GENERAL SCIENCE
FOR THE
INTERMEDIATE SCHOOL

G. H. LIMPUS
J. W. B. SHORE

MACMILLAN

Same as Elementary General Science by Lumpus and Stone

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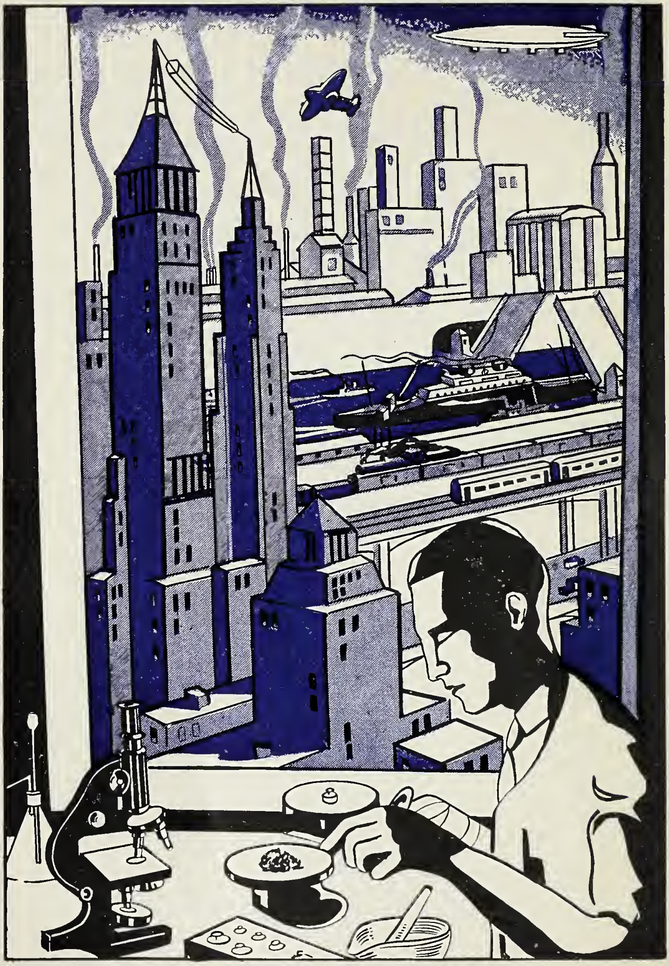

From the Laboratory of the Scientist

GENERAL SCIENCE FOR THE INTERMEDIATE SCHOOL

BY

GEORGE H. LIMPUS, B.A.
HEAD OF THE DEPARTMENT OF GENERAL SCIENCE
KITSILANO JUNIOR HIGH SCHOOL
VANCOUVER, B.C.

AND

JOHN W. B. SHORE, B.A.
VICE-PRINCIPAL, KITSILANO JUNIOR HIGH SCHOOL
VANCOUVER, B.C.

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FOREWORD

Psychological theory and the practical testing of experience have given General Science a secure place in the secondary schools of Canada as an introduction to the later study of specialized sciences. The development of the Junior High Schools in a number of the provinces is now leading to a study of General Science in the seventh and eighth grades, where it is displacing what has been called Nature Study.

The pupils of these grades are in the secondary stage of education; they are beginning to show the characteristics of adolescents and the field of their interests is broadening. Nature study, while an appropriate pursuit in the earlier grades of the school, does not challenge these broadening interests, nor does it answer the questions which the pupils are asking as they seek to understand their environment. In general science the pupil is taught to reason and to draw correct conclusions from facts. To do this the scientific method, as followed in the special sciences, is practised. But while the methods of General Science are essentially the same as the methods of the particular or special sciences, the interests of the pupils at the age of those for whom this book is written, are not confined to any one of the formal sciences. These pupils see the phenomena of their environment unclassified, and they desire to investigate them. General Science affords the approach to this investigation. It is the happy middle course between nature study and formal science.

Authorities consider the following to be among the special aims of General Science:

1. It should develop a type of problem-solving ability which renders the pupil capable of independent thinking.
2. It should develop the habit of accurate observation of the laws of cause and effect as exemplified in the scientific phenomena with which the child comes in contact.

3. It should present information about a wide range of scientific phenomena and experience, and should form an adequate basis for a wise selection of courses in the specialized sciences in the Senior High School.
4. It should develop habits and understandings which make for healthful personal living.
5. It should give the pupil a fund of scientific experiences, and provide opportunities for his natural interests to manifest themselves.
6. It should correct common superstitions and practices that have arisen out of ignorance of the laws concerning life and matter.
7. It should impart information about those appliances which science has developed for the greater convenience, comfort and richer life of the home.
8. It should develop an appreciation of the importance of the knowledge of scientific research to modern life, and a stimulation of accurate observation and investigation.
9. It should develop the habit of observing natural phenomena as an enjoyable experience in leisure time.
10. It should give information that is necessary to an adequate understanding of the scientific concepts found in the daily press and in the non-specialized literature read by the average man or woman.

In order effectively to accomplish these aims the subject matter of science as presented in the class-room should reflect the real interests of the pupils. It should reveal to them opportunities of applying their newly acquired knowledge. In order that the interest of the pupils may be held the material should cover as wide a range as possible. Because of this breadth of range, economy of time becomes important. A suitable text book aids materially in presenting the course in a minimum of time.

Many admirable text books upon General Science have been written. Not all of these texts, however, are adaptable to the peculiar conditions where General Science courses are being newly

incorporated in the curriculum. The authors of this text book have borne in mind that there are schools where elaborate apparatus is not available. The experiments described have been so devised that essential principles are demonstrated with the simplest of apparatus.

In selecting material the authors have been guided by their personal experience in teaching General Science over a number of years and by the results of the various researches which have been made to determine the proper content of a General Science course. It is generally agreed that interest is of extreme importance in an introductory book in any subject. The content or subject matter of this book has been selected upon the basis of interest and it is believed, has been presented in such a way as to capture and retain it.

With these ends in view every effort has been made to construct a readable text. The language is plain and straight-forward; the story of science which it contains is a steadily unfolding and continuous story. The vocabulary presents no unnecessary difficulties. With the exception of new scientific words, which are explained as they are introduced, the vocabulary is simple. It is possible therefore, for the majority of pupils to read the book with rapidity and with clear comprehension of its meaning.

The experiments in the text are illustrative of the reading material. They are so inserted as not to detract from the readability of the book.

H. B. KING,
Kitsilano High Schools,
Vancouver, B.C.

PREFACE

In planning this text, the authors have aimed at teaching the pupil to draw correct conclusions from facts rather than to present a mass of information. Each chapter develops naturally by the inductive-deductive method, so that the pupils become familiar with general principles and then use these principles in solving the problems suggested at the end of the chapter. In developing each experiment a plan of attack is followed which indicates the line of reasoning most suitable for solving the problem.

The subject matter of the text has been so organized as to obtain the maximum teaching value. At the beginning of each chapter are a number of thought-stimulating questions. It is not intended that the pupil's progress should be held up until he has answered all of them as they are intended only to stimulate the interest of the pupil and to orient him towards the content of the chapter. After the material of the chapter has been mastered the correct answers for the questions should be required.

At the end of each chapter is appended a list of "guide words" and "signpost sentences". The guide words indicate the increase of vocabulary acquired through the understanding of the chapter. The signpost sentences contain the gist of the principles established. It is not imagined that there will be found today teachers who will expect these sentences to be memorized in a mechanical fashion. However, they should not be read casually and then forgotten. They should be understood and intellectually mastered. In order to motivate the learning of them, essential words have been omitted. The omitted words are to be found in the lists of guide words. To find the missing words and insert them in their proper places makes an excellent class exercise and affords a basis for profitable discussion.

The questions at the end of each chapter have been graded.

They are divided into two groups. The "questions on the chapter" can be answered from a knowledge of the text so that the ability to answer these questions correctly denotes an understanding of the text and the scientific principles involved in the lessons.

The "special problems and practical applications" are designed for the more rapid worker. They give him scope for his initiative in applying the principles he has learned to the solving of new problems. In this group are included suggestions for the study of related topics outside of the class room. It is not to be thought that these questions exhaust all the possibilities. No doubt the teacher will make additions to them. This grading of the questions affords an opportunity to help the weaker students while the more advanced are occupied otherwise.

In Appendix I are to be found chapter tests on Unit I along with a mastery test on the whole unit. These tests are put in one or other of the common "objective" forms. This is done to suggest how this type of testing may be used for the saving of time. It is hoped that the particular forms indicated will not be used exclusively, but that the teacher will devise similar tests to discover what mastery of each unit his pupils have obtained.

Pupils who have developed an interest in science desire to supplement the experiments of the class room with home experiments. There has been added to each chapter a suggested list of experiments which can be done with simple apparatus and materials.

It is suggested that each pupil should be provided with a Science Record Book in order that he may keep a neat and orderly record of his work.

The authors are indebted to Mr. H. B. King, Principal of the Kitsilano High Schools, not only for his valuable advice on educational practice but also for his critical reading of the manuscript and proofs. They wish to thank Mr. H. B. Fitch, Principal of the Templeton Junior High School, for his assistance in the organization of subject material; Miss M. L. Elliott for contribu-

tions to the objective tests; Mr. L. Manuel for many of the original illustrations; Mr. J. T. Young; and their many colleagues who have contributed so freely towards the completion of the text.

The authors are also indebted to various government departments, both federal and provincial, to scientific institutions and to commercial concerns who have contributed illustrations. Specific acknowledgment will be found accompanying these illustrations in the text. The authors wish also to thank Macmillan and Co. Limited, London, the Macmillan Company, New York, and the Macmillan Company of Canada, Limited, Toronto, for permission to use illustrations from their publications.

G.H.L.
J.W.B.S.

CONTENTS

PART I

PART II

PART I

CHAPTER I

INTRODUCTION

Science Explains

The Changing World. Probably you have often heard your grandparents or elderly friends speak like this: "When I was a boy, there were no electric lights nor street cars. We never dreamed then of aeroplanes nor of automobiles. It seems only yesterday that the first successful aeroplane flight took place, and now men fly across the ocean. What a different world it has become! We have motion pictures to amuse us; by merely turning a dial on a radio we hear songs and stories from distant lands. Almost daily some new discovery is made. How the world has changed since I was young!"

In former centuries man's progress in science was not rapid like this, but slow. Within the last half century such rapid strides have been made that a complete change in our ways of living has taken place. Your grandfather has seen wonderful changes during his lifetime. The real cause of these changes has been the use made of facts learned through scientific experiments. Scientists have found that the way to learn about nature is to learn by actual experimenting and by careful observation. They have found that guess-work is not reliable, and that opinions are not to be trusted unless they are tested and proved by actual experiment. For example, people who are not scientific often think of an "empty" jar as being really empty. It may surprise you to learn that science can prove that the "empty" jar is quite full. If you doubt this follow the scientist's plan and prove for yourself that the "empty" jar is really full.

Science Proves. If you can show that it is impossible to put

anything into the jar without removing something from it, then you will know that the jar is not empty.

Secure an "empty" jar and a basin of water. Turn the jar upside down (Fig. 1). Thrust its mouth downward into the water. Observe that the water does not enter the jar. Tilt the jar slightly. Notice that bubbles escape from it and that water enters as they escape. Why did not water enter at first? Because the jar contained air. So long as the jar was full of air nothing else could go in. You might argue that a fly could go into the supposedly empty jar. That is quite true, but when the fly goes in some of the air comes out.

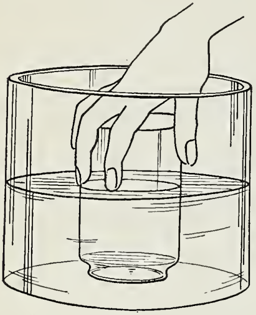


Fig. 1.
Note that the water does not enter the bottle.

In your work in General Science you will perform many such experiments. You will learn new facts and will form new ideas. You will acquire much interesting and useful knowledge. You will be surprised to learn that the knowledge gained from such a simple experiment as we have just done enables men to build huge bridges across wide rivers, and to place foundations of lighthouses on submerged rocks.

Applied Science. At first you may not see the connection between our simple experiment and the building of a bridge. Before the bridge could be built foundations had to be laid on the bed rock beneath the mud of the river bottom. The mud had to be dug away before the concrete could be poured to form the piers which support the bridge. This work had to be done under water. In order to keep the water away from the men as they worked, a steel tank like a huge jar (Fig. 2), open at the bottom, was forced into the river. The air in the tank kept the water out just as the air in the jar kept out the water in the basin. Conse-

quently, the men inside the tank were able to work in safety on the river bottom. Such tanks are called **caissons.**

The famous Victoria Bridge (Fig. 3) across the St. Lawrence River at Montreal is an example of a bridge made possible by the use of caissons. Of course a great many other scientific facts had to be mastered before such a bridge could be built. These facts also were learned by experimenting, for scientists are constantly experimenting and learning new facts about the world in which we live. The foods we eat, the clothes we wear, the comforts we have around our homes, our houses, our ways of travel, our health and our pleasures have been improved and are still being improved through scientific experiments.

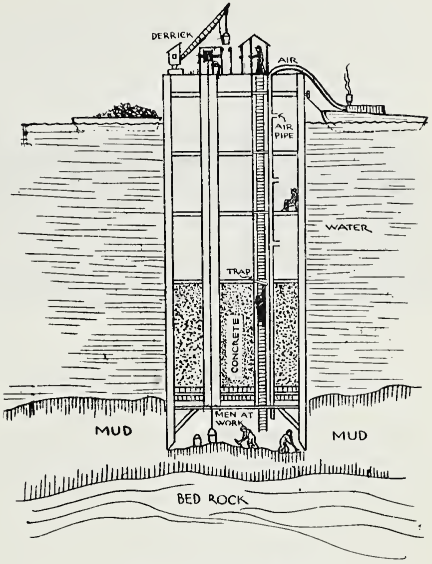


Fig. 2.—The Caisson
What prevents water from entering the caisson?

Many things which are common today were a few short years ago quite unknown. When your grandfather was a boy, there were no electric lights, no telephones, no automobiles in common use. Even when your father went to school there were no neon signs, no radio broadcasts, no "talkies". You yourself can name many new things which have come into use during your own

lifetime. So many have been the discoveries made within the last few years that this age is often called the "Scientific Age".

Courtesy Montreal Water Board

Fig. 3.—Victoria Bridge, Montreal
The building of this bridge was made possible by the use of caissons.

The Scientific Method. Why should so many scientific improvements have been made during recent years? They are the result of the development of the scientific method. This method is simply the finding of answers to problems by means of carefully thought-out experiments. For centuries men had to be content with horse-drawn carts for travel, and with candles for light, simply because they did not know how to gain new knowledge scientifically. They did not have the scientific method.

How does one learn scientifically? Here is the method which the scientist follows:

1. He selects a problem to solve.
2. He decides upon a plan by which the problem may be solved.
3. He procures the apparatus and materials which he will use in working out his plan.
4. He selects a method by which his plan may be carried out.
5. He makes careful observations and makes a record of his observations.

6. He draws sensible conclusions based upon his observations.
7. He tries to apply his discoveries usefully.

Did we follow this scientific method in doing our experiment with the "empty" jar? Review the experiment carefully, and compare it with the plan just given.

Scientists use the facts gained in this way to increase human knowledge. They write down the facts which have been discovered and classify them in proper order so that they may be used again. *This classified knowledge is Science.*

So vast is the field of science and so numerous are the facts which have been recorded that it is necessary to subdivide science into Special Sciences. All knowledge concerning chemicals is classified under the heading of "Chemistry". Chemistry is a special science. "Astronomy" is the science of the stars; "Biology", the science of living things. There are many other special Sciences of which you will hear later.

Scientists of Many Nations. The scientific discoveries of such men as William Harvey, Michael Faraday, Louis Pasteur, Guglielmo Marconi, Benjamin Franklin and Alexander Graham Bell have made them famous. The scientific spirit which urged them on is found in all countries: it is universal. You, too, will have an opportunity of contributing to science. Who knows but that the study of General Science may be the beginning of your success as a scientist? To be successful, be sure to make a proper start. Make up your mind to master the facts. Write in a "Science Record Book" a neat and orderly account of all you do and of all you learn. With patience, perseverance, and a determination to succeed you can go far.

There is a world of knowledge to be gained from the common things with which you come in contact daily. To succeed in science you must master this knowledge of your environment or surroundings.

See Appendix for Test on Chapter I.

UNIT I

WATER AND HUMAN WELFARE

CHAPTER II

WATER IN MANY FORMS

Can you answer these questions?

Note. Do not write answers to the questions which are given at the beginning of each chapter. They are for class discussion only and serve as an introduction to the lesson. See how many of these problems you can answer before reading the chapter. Then, if you read the chapter carefully and understand it thoroughly, you should be able to answer them all. Test yourself on the questions again. If you can answer them correctly it is a sign that you are mastering the chapter.

1. Will the oceans ever dry up as ponds do?
2. Does water ever become invisible?
3. What caused the oceans to become salt?
4. Why do not the oceans become larger as the rivers of the world continue to pour their waters into them?
5. Can water ever fall twice as rain?
6. From where does the dew that is found on grass come?
7. The air in the room contains millions of specks of dust. How could you prove this?
8. What becomes of the water when a kettle boils dry?

Water and Human Welfare. As a beginner in the subject you are apt to think that a study of science is a study of rare chemicals with the complicated apparatus to be found only in the science laboratory. You may not at first realize that the most interesting and important facts of science are to be learned from such ordinary substances as water, soil and air.

Very few boys or girls understand the importance of such a

common substance as water. Since water is so very plentiful they think of it as being of little interest or value. Water is found everywhere. The oceans, vast trackless wastes of water, cover three-quarters of the earth's surface. Lakes and ponds are filled with water. Rivers run with it. It falls as rain. It is found as dew in the morning. You sprinkle your lawns and gardens with it. You swim in it; you wash in it. It enters into your body; over half of your body is composed of water.

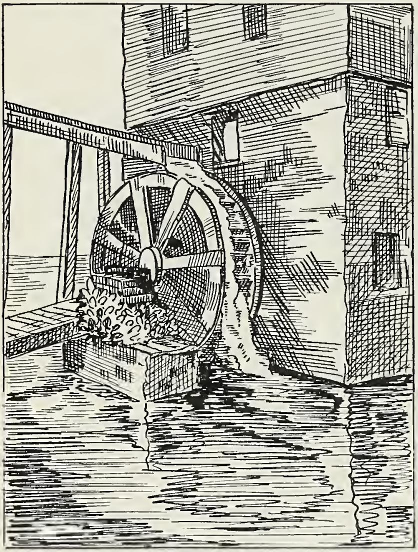


Fig. 4.—The Old Mill
An early use of water to do work.

If you were to be deprived of water, in a very short time you would die of thirst. You can live much longer without food than without water. Moreover, the plants and animals which produce your food depend upon water. They cannot live or grow without it. Have you ever seen a desert or a picture of a desert? How dry it is, how dusty and desolate! Plant life is impossible on a desert which is completely waterless.

Water as a Map-Maker. Have you ever noticed, when studying the map of Canada, that most of the towns and cities are built near water? Many of our cities have grown upon the former camp sites of the Indians. The first settlers selected these places

for their settlements because of the water which was there. The settlements could be reached by boat or canoe. As the settlements grew into towns, the rivers, in many cases, provided power to turn mill wheels (Fig. 4) or, still later, to develop the electrical power which is so necessary in this modern age.

Now that you realize the importance of water in your daily life you will understand why communities go to such trouble to secure pure fresh water. The water of the ocean, being salt, cannot be used for drinking. Fresh water, however, may be obtained from lakes, rivers and streams. If these do not exist in the locality, water may be obtained from springs or from wells dug in the ground. In some places the only source of water is the rain. The rain-water is caught and stored in tanks or cisterns for future use.

Fresh Water from Rain. Whence comes this seemingly endless supply of fresh water? What keeps the lakes full, the streams flowing, the springs bubbling and what keeps the wells from going dry? Our chief source of fresh water is the rain. Fresh water is scarce where rainfall is scarce and is plentiful where rainfall is plentiful. You already know that rain does not come from a clear sky but from a cloudy one. Rain comes from clouds. In order to understand the causes of rainfall you must first understand the nature of clouds. Let us follow the raindrops into the clouds to see if we can learn the cause of rain.

Water in the Air. Quite often, from out of a clear summer sky, a thundercloud grows, apparently from nothing. Soon rain comes pouring down. The cloud must have contained the water which made the rain. Since the cloud was formed in a clear sky this rain-water must previously have been in the air in an invisible form. Can you prove this statement by the scientific method?

PROBLEM

To show, by the scientific method, that air about us always contains water.

Plan for Solving the Problem. You know from observing snow and ice upon mountain tops that the upper air must be colder than the air close to the ground. Clouds are formed in the upper air. Does the fact

that the upper air is cold have anything to do with the forming of clouds? You can cool some air to see if this is so.

Apparatus and Materials Required. A beaker or glass jar, ice and water (Fig. 5).

Method. Dry the outside of the beaker thoroughly. Fill it with a mixture of ice and water. Allow the beaker to stand for a few minutes.

Observation. 1. Does the air surrounding the beaker become cooled? 2. Is there any substance forming on the outside of the beaker? 3. What is this substance?

Conclusion. 1. Could the moisture which was formed have come through the glass? 2. From where do you think it came? 3. Does air contain moisture? 4. How can the moisture be removed from the air? 5. Which holds more moisture, warm air or cold air?

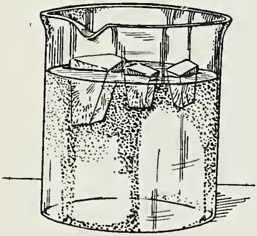


Fig. 5.—An Experiment to Prove That Air Contains Water Vapour

N.B. You should keep a record of all your experiments in your "Science Record Book". The scheme outlined above should be followed. These experiments are important and should be mastered thoroughly.

Water Vapour and Dew. The experiment you have just completed teaches you that there is moisture in the air. This moisture, however, is not wet like the water with which you are familiar, nor can it be seen like ordinary water. This water of the air is called **water vapour.** It exists, not as a *liquid* but as a *gas*. You have also learned from your experiment that air always contains some water vapour and that when you cool the air the water vapour in it *condenses* to *liquid* water. The experiment, therefore, teaches you that warm air will hold more vapour than cold air, and that you can remove water vapour by cooling the air. The water vapour will condense on a cold object in the form of tiny droplets or **dew.** By your experiment you found that the warm air of the room contained much water vapour. When it came into contact with the cold sides of the beaker this air became cooled and could not hold all the water vapour that was in it. Some of the water vapour, therefore, condensed to form dew.

People who wear glasses often notice that a mist is formed on their glasses when they go into a warm room from the cold air outside. The warm air of the room contains much water vapour which when cooled by coming into contact with the glasses condenses on them as dew.

After sunset on clear evenings, the ground cools very rapidly. The air just above the ground is cooled by contact with it. The water vapour in this air condenses as dew upon the ground, the grass and the leaves. In summer, dew is usually abundant because the warmer summer air contains much water vapour.

Courtesy Publicity Bureau, Vancouver, B. C.

Fig. 6.

Aviators report that the fleecy white clouds are similar to fog.

Fogs and Clouds. You have now discovered how dew is formed. Can you account in the same way for clouds? No doubt you would like to obtain a portion of cloud to study it. It will not be necessary to go aloft in an aeroplane in order to have

experience of clouds. Fogs and mists are just like clouds except that they are close to the ground. Mountaineers and aviators report to us that the fleecy, white clouds we admire so much are only fog (Fig. 6). It is therefore plain then that if you can find the causes of fog you will be able to form an opinion as to the cause of clouds. Have you ever breathed against a cold window pane? Did you notice the dew which formed upon it? Your warm breath must have contained water vapour. Have you ever seen your breath turn to fog on a cold, winter's day? The water vapour of your breath condensed on little particles of dust that are always in the air.[1]

There were thus formed millions of tiny drops of water. These little drops are too light to fall to the ground, and so they float around in the air as a visible mist or fog.

When cold winds or sudden changes in temperature cool large bodies of air, the water vapour in the air condenses on the dust particles and we have a fog.

A cloud is, as you have learned, a fog in the upper air. It is produced by the cooling of the air just as ordinary fogs are produced. Air containing water vapour becomes cooled as it rises to the higher regions of the atmosphere. The water vapour in it condenses. A fog or cloud results.

How Clouds Produce Rain. The droplets of water which compose or make up the cloud grow larger and heavier as more water vapour condenses upon them. They may be jostled about by the wind and run together, so that they increase in size until they become heavy enough to fall as rain. When the water vapour in the air condenses at freezing temperatures, crystals of ice or snowflakes, instead of droplets of water, are produced.

The rain which falls to earth fills lakes, ponds and streams. It is the never-ending source of man's fresh water supply.

Renewing the Supply. You may have been wondering why

1 You can see the dust particles of the air when a beam of sunlight shines across a darkened room through a crack in the blind. The light is reflected from the dust particles. You are less likely to notice them when the room is completely illuminated or lighted up.

the air does not lose all its water vapour, since it loses so much of it as rain, snow or dew. It must be clear to you that if the supply is to be kept up water must be continually going back into the air.

PROBLEM

Can you demonstrate that liquid water does become invisible water vapour?

Plan. If you can show that water, when left in contact with air disappears, then it will be clear that the water has gone into the air as vapour.

Apparatus and Materials. Two saucers (A and B as in Fig. 7), a piece of glass large enough to cover one of the saucers, and some water.

Method. Fill each saucer with water. Put both saucers on a window sill. Cover one with the glass. Allow the saucers to remain on the sill for several days.

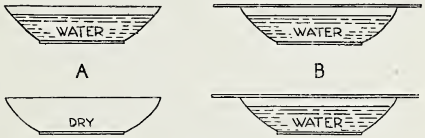


Fig. 7

The water evaporates from the uncovered saucer (A).

The water does not evaporate from the covered saucer (B).

Observation. 1. Does the water disappear from both saucers? 2. From which saucer does it disappear? 3. Could you see the water leaving the saucer?

Conclusion. 1. Where did the water go? 2. Why did the water disappear from the open dish but not from the covered one? 3. Do you think the water would have gone from the second saucer if it had not been covered? 4. How does this experiment show you that water went into the air as water vapour?

Water Evaporates. You have learned from this experiment that water when left in contact with the air disappears into it. It seems to dissolve in the air just as sugar dissolves in water. It disappears just as completely. We say that the water has **evaporated.** The visible water has become invisible water vapour.

You can form some idea of the enormous amount of evaporation that takes place by comparing the vast ocean surface with the surface of the water in the saucer. Add to this the evaporation from rivers and lakes, from the soil and from the leaves of

plants, and you will readily understand how the water supply of the air is maintained.

The Sun Supplies the Energy. Water will evaporate or become water vapour when the air is warm. It condenses to form water again when the air is cooled. Heat, then, is needed to perform this work of evaporation. What is the source of the heat? The sun is the source. If it were not for the heat of the sun there would be no evaporation. Air would contain no water vapour. There would be no clouds nor rain. The sun, then, is the source of the energy which causes untold millions of tons of water to leave the ocean, to enter the air as water vapour, and to fall again on the earth as rain.

Why Rain-Water is Pure Water. Rain-water is pure water. Rain, as you know, is produced by the condensation of water vapour. The water vapour comes from oceans, lakes, swamps and streams. Ocean water contains salt. Swamp water is dirty, and lake or river water often contains filth which makes it dangerous to drink. How is the pure rain-water separated from these impurities? A simple experiment that you can do for yourself will answer this question.

PROBLEM

What becomes of the salt when ocean water is evaporated?

Plan. You can evaporate a little ocean water to see what happens to it. (If ocean water can not be obtained, dissolve a teaspoonful of salt in a cup of water.)

Materials. Salt, ocean water, or salt water.

Method. Place the saucer of salt water upon a window sill and observe it from time to time.

Observation. 1. Does the water evaporate? 2. Is there anything left in the saucer when the water has all evaporated? 3. What is the taste of the material, if any, which is left in the saucer?

Conclusion. 1. Does the salt which is dissolved in water evaporate when the water evaporates?

This experiment shows why rain-water is pure water even though the water vapour which produced it came from the salt ocean or from a dirty swamp. From the experiment you learn also why the oceans have become salt. Rain which has washed through the earth for ages has dissolved salt in the soil. This

salt water is carried by rivers and streams to the ocean. As the water of the ocean evaporates the salt remains behind, and so the ocean becomes more salt each year.

The Water Cycle. Would you have thought, at the beginning of the chapter, when you began to trace the raindrop to its source, that you would find it in so many varied forms? You found it first as a liquid in the lakes and oceans. Then by evaporation it became a gas (the water vapour in the air). Then the air became cooled and the water vapour condensed to form dew, mist, fog or clouds. The tiny droplets in the clouds became larger and heavier and fell as rain. The rain filled the lakes and rivers, and the rivers carried the water back to the ocean. The water thus

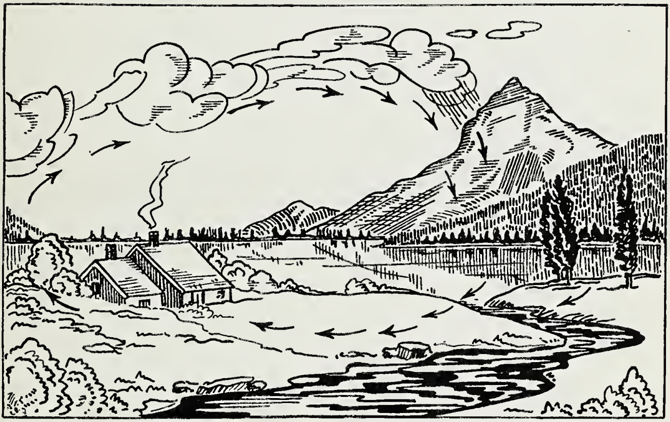


Fig. 8.—The Water Cycle
Trace the cycle step by step.

returned to its starting point. From the ocean the water evaporates once more and the process is repeated.

Water, aided by the heat of the sun, seems to follow an endless *cycle* or circle—from liquid to vapour, from vapour to clouds,

from clouds to rain and from rain back to water again. This cycle is called the **water cycle.** (Fig. 8). It is of great importance to life. It circulates the water which is the life-blood of the earth.

Guide Words

chemical	water vapour	visible
apparatus	gas	invisible
laboratory	dew	illuminate
dissolve	rain	crystals
impurities	fogs	snowflakes
energy	clouds	science
temperature	condensation	water cycle
desert	evaporates	liquid
atmosphere	dust particles	water
water supply		

Sign-Post Sentences

1. Over three-quarters of the earth's surface is covered with ....
2. The location of many communities was determined by the ....
3. Fresh water supply depends upon ....
4. .... is produced from clouds.
5. Clouds result from the .... of water vapour on dust particles in the air.
6. Water .... to form water vapour.
7. Warm air can hold more .... than cold air.
8. .... are clouds close to the earth's surface.
9. .... is caused by the condensation of water vapour upon cold objects.
10. Water vapour is an .... gas.
11. The heat of the sun furnishes the .... which keeps water going in an endless ....; from water to vapour, from vapour to clouds and from clouds back to water again.
12. When water evaporates the .... in it are left behind.

When the signpost sentences are completed they will be a summary of the chapter. If you cannot fill in the blanks from memory, the list of guide words will help you. Many of the guide words are new for you. You should know how to spell them all. You should also be sure that you understand all the signpost sentences before you begin a new chapter.

Questions on the Chapter

1. What causes dew to form on the grass on a clear summer's night?
2. What causes drops of water to collect on the outside of cold water pipes?
3. Why do one's eye-glasses become "fogged" with moisture when one enters a warm house on a cold winter's day?
4. Why does your breath appear as a fog on cold days?
5. Why do clothes dry more quickly on some days than on others?
6. What becomes of the water when wet clothes on a clothes-line dry out?

7. What has caused the oceans to become salt?
8. What is a fog? How is it formed?
9. How are clouds produced?
10. How do clouds produce rain?
11. How do we know that the air contains millions of dust particles?

Special Problems and Practical Applications

1. How could you hasten the drying of clothes? Give reasons for the method you would use.

2. The breath becomes visible on a *cold* day because the water vapour in it condenses into droplets to form a cloud. How could you show that we breathe out water vapour on *warm* days as well?

3. In some countries salt is obtained from ocean water. Can you suggest a way in which this is done?

4. In Windsor, Ontario, brine (a mixture of salt and water) is pumped from wells. How can the salt and water be separated?

5. Evaporated milk and dehydrated fruits and vegetables have had some of their natural water removed by evaporation. Why is this done?

6. Why should there be more rainfall on the coast of British Columbia than on the coast of Quebec?

7. The average annual rainfall in Vancouver is 62 inches. At this rate how many cubic feet of water will fall on a square foot of land in a year? How many cubic feet will fall in a year on a city lot 50′ x 120′?

8. On an outline map of Canada mark the amount of rainfall in inches for the following places: Vancouver, Prince Rupert, Calgary, Regina, Winnipeg, Toronto, Montreal, Quebec, St. John and Halifax. You can secure this information from books in the library. Does the amount of rainfall have anything to do with forest growth? Find the amount of rainfall on 100 square feet of three of the above places.

9. Read Shelley's poem "The Cloud". Point out the passages which show that he had a scientific understanding of how clouds are formed.

Home Projects

(1) If it is possible secure some sea water: put a measured pint in a clean, shallow dish and allow it to evaporate. After all the water has evaporated, collect the salt and weigh it. Calculate the amount of salt in a gallon of sea water.

(2) Place equal quantities of water in two saucers. Put one of them in a closed cupboard and put the other outside of the house. In which does the water evaporate the more quickly?

(3) Place a cold plate near the spout of a kettle in which the water is boiling. Account for what happens.

CHAPTER III

SOURCES OF MAN'S WATER SUPPLY

Can you answer these questions?

1. From where does the water come that supplies a well?
2. What causes artesian wells?
3. What causes springs to flow from the ground?
4. Why do streams continue to flow for a long time after the rainy season has passed?
5. Plants must have a continuous supply of water which they get from the soil. How is the supply kept up during the summer when for long periods there is no rainfall?

Tapping the Water Cycle. In your study of the water cycle you learned that the processes of evaporation and condensation are going on continually. In the water cycle the impure water of swamps and oceans is converted into pure fresh rain-water. Upon rain-water man depends for his continued supply of pure drinking water. You may question this statement. You may argue that man does not often collect rain-water to drink. You may say that he digs wells or dips his water from a stream or lake. You know that he may get water from a cool spring or an artesian well. These arguments are all quite true, but they do not tell the whole of the story. Whence does the water come that fills the wells, streams and lakes?

To answer this question, let us see what becomes of the rain after it has fallen. After a heavy rain you have observed, that much of the water which fell flows away in ditches and streams. The water which runs off the surface of the soil in this manner is called "run-off" water. The smaller streams run together to form rivers. The rivers flow into lakes or the ocean. Much of

the rain thus travels back to the ocean. In some countries where the rainfall is limited the "run-off" water is caught and stored in reservoirs, or artificial lakes, for future use. The Assuan Dam across the River Nile is man's greatest attempt to store water in this way. The Bassano Dam in Southern Alberta (Fig. 9) is another example. These two reservoirs were built to conserve or save water for irrigation. Many cities have reservoirs of "run-off" water stored for domestic, or family use.

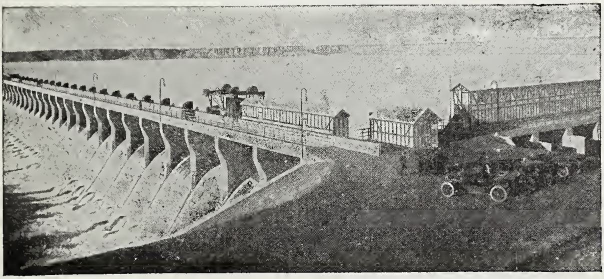


Fig. 9.—The Bassano Dam in Alberta
This dam was built to store run-off water. Du ing the dry season this water is used to irrigate nearby farms.

The Soil is a Reservoir. Not all the rain which falls runs off in the way which has been described. You have observed that the soil remains damp for a long time after a rain. It is clear that the soil must contain much of the rain-water. Soil is composed of small particles of rock and other material. Some of the water sticks to the surfaces of these soil particles. A great deal of it passes through the spaces between the particles. What becomes of this water? Let us do an experiment to answer this question.

PROBLEM

To discover what becomes of the rain-water which seeps into the soil.

Plan. If one were to dig down into the soil he would find the top soil to be made of loose particles. Underneath the loose soil he would find a

layer of solid material through which water will not pass. If you make a model of the soil you should be able to observe how the water behaves.

Apparatus and Materials Required. A lamp chimney or a large glass tube with straight sides. A large cork to fit one end of the chimney. A small glass tube of the same length as the chimney, some earth, and a piece of cellophane paper.

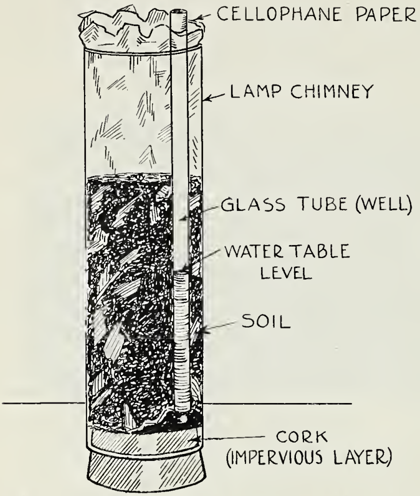


Fig. 10.—A Model of a Section of the Soil Showing How Soil Water Enters a Well

When the well is emptied why will it fill up again?

Method. Insert the cork tightly (Fig. 10) into one end of the chimney. Place the small glass tube in the chimney so that it lies along one side. Line the inside of the chimney with cellophane paper. Pour earth into the chimney. This model represents a section of the soil. The cork represents the layer through which water does not pass easily. The small glass tube represents a hole dug into the soil.

At intervals pour small quantities of water on the soil in the chimney.

Observations. 1. Does the water seep into the soil? 2. How long does it take the first lot of water to seep into the soil? 3. Does the second lot of water seep in more quickly than the first? 4. Can you notice the soil becoming moistened as the water goes downward? Add water slowly until it appears in the bottom of the smaller tube. Continue to add water. 5. Does the level of the water rise in the smaller tube? When there is about an inch of water in the smaller tube set the model aside for a few minutes. Examine it again at the end of that time. 6. Has the water risen any higher in the small tube? 7. Is the soil above the water-level as wet as the soil below?

Conclusions. 1. Why was it possible for the water to go into the soil? 2. Why was it possible to add more water after the soil was all moist? 3. Why did the water rise in the glass well? 4. Why did it continue to rise after the apparatus was set aside? 5. Why did the water stop rising in the well? 6. Why did the lower particles become more moist than the upper ones?

A Peep Under the Soil. Some of the rain-water seeps down through the porous surface soil until it reaches a layer of clay or solid rock; here it is stopped. Since this layer prevents the water from passing through it is said to be *impervious* and is called the *impervious layer* (Fig. 11). Beneath all soils there is a layer of impervious material. The water collects above the impervious layer and fills the spaces between the soil particles. The level reached by this underground water is called the *water table.*

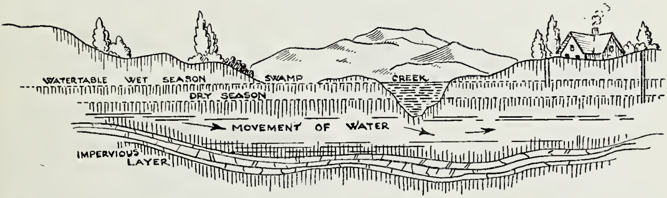


Fig. 11.—A Section of the Soil Showing Wet Season and Dry Season Water Tables.

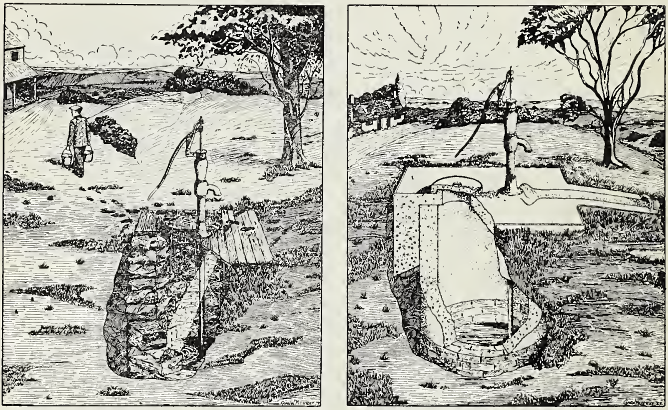
What effect will the lowering of the water table in the dry season have on (a) the spring? (b) the swamp? (c) the well?

The water table is usually some distance below the surface of the soil. When the water table reaches the surface of the soil the earth becomes wet and soggy and a bog is formed. If the water table rises higher than the surface a pond or lake is formed. If a hole is dug into the ground deep enough to reach below the water table the water flows into the bottom of the hole. Such a hole in the ground is a well. The level of the water in a well stays at the level of the water table. During the summer when there is little rain, the water table lowers because of evaporation from the soil, and because a great deal of the underground water seeps back to the rivers and runs off.

While it is soaking into the soil the water often dissolves lime or other materials. It is then said to be *hard water.* If hard water is used for washing, the materials dissolved in it make it difficult to form a lather of soap. It is therefore difficult to wash

with hard water. Hard water may, however, be quite good for drinking purposes. *Soft water* is rain-water in which there is very little dissolved material. Soft water makes an excellent lather with soap.

Selecting a Well Site. The most promising place in which to dig a well is a valley. The water table is sure to be closer to the surface there than on a hill. However, there are other important things to be considered when choosing the location for a well. The most important point is that the well should be



Courtesy Ontario Department of Health

A Fig. 12 B

Why is it safer to drink water from well B than it is to drink from well A? Why is well A an unsafe well?

placed where there is no danger of filth getting into it. Filth is likely to contain disease germs.[1]

A well which contains disease germs is a danger to health. You have learned that water seeps down through the soil. In so

1 Germs or bacteria are very tiny living plants or animals. They are so small that thousands of them could be placed on the head of a pin. A germ can not be seen without the aid of a powerful microscope. Disease germs are able to grow in people and produce poisonous substances which cause sickness. There are many germs, however, which are quite harmless to human beings.

doing it is *filtered.* Germs and other solid impurities are strained out of it. If the well is not deep enough the water table will be so close to the top of the ground that the surface water will not be properly filtered before it gets into the well. A shallow well is likely to contain disease germs, especially if it is near a barn or outhouses. (Fig. 12).

Study the diagrams in Figure 12. Which is the better well? A good well is not merely a hole in the ground. A good well must be *cased* or lined. The casing prevents the sides from caving in. It also serves to prevent the surface water from running into the well. Before the surface water enters the well it should filter down and enter from the bottom of the casing. For this reason concrete makes the best lining for the upper part of a well.

Artesian Wells. In various parts of the country water is

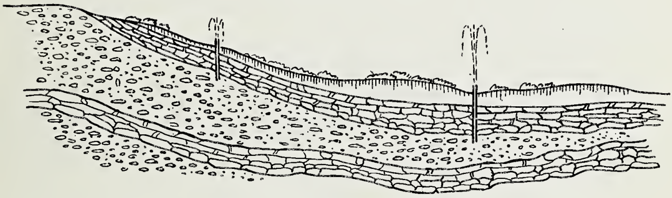


Fig. 13.—Artesian Wells
Tell how this formation of the earth makes possible the artesian well.

secured from artesian wells (Fig. 13). A pipe is driven into the ground, sometimes to a great depth. If the location is suitable, water gushes from the pipe. Some artesian wells are found in places where there is little rainfall. Nevertheless, they give an abundant supply of water. What are the conditions which make artesian wells possible?

Artesian wells are possible only where the ground formation is suitable. If the impervious layer is broken through or washed away, water gets beneath it. The water seeps into sand or gravel underneath the impervious layer and travels until it collects in a

depression or basin. Water sometimes flows many miles underground in this manner. The water imprisoned under the impervious layer is under pressure. When a pipe is driven through the impervious layer the water escapes to the surface of the ground. The diagram shows this clearly.

A Reserve of Water. Perhaps you have wondered why rivers continue to flow long after the run-off water is all gone. Your knowledge of the water table will help you to solve this problem. If the level of the water in a river is higher than the water table under the soil, water will seep into the soil from the river (Fig. 11). On the other hand, if the level of the river should drop below the water table, water will seep into the river and so keep it flowing. During the dry season, when the water table sinks below the river bed, the river goes dry. The soil is an enormous natural reservoir which keeps the rivers supplied long after the rains have ceased.

On the mountain tops, there is another great natural reservoir. In the winter time snow accumulates on the mountains to form glaciers. The cold of the high regions prevents the glaciers from melting until the warmth of summer returns. We might say that this water is kept in cold storage.

Guide Words

"run-off" water	soft water	impurities
reservoir	hard water	mineral
glaciers	filters	seepage
irrigation	impervious layer	surface water
seep	water table	germs
pressure	muskeg	depression
artesian well	storage	water cycle

Signpost Sentences

1. Man's fresh water supply comes from the ....
2. Much of the rain flows away as .... water.
3. Water containing dissolved minerals is called ....
4. Beneath all soils there is an .... above which water collects.
5. The level of the water in a well stays at the level of the ....
6. The soil .... the water which passes through it.
7. The soil is an enormous natural ....
8. Glaciers keep water in cold ....

Questions on the Chapter

1. Why do wells sometimes go dry in the summer?
2. What becomes of the "run-off" water after a rain?
3. What provinces contribute water to the St. Lawrence River?
4. What danger is there in drinking water from an unlined, shallow well?

Special Problems

1. Why is spring water and well water usually quite clear?
2. Sloughs are often found beside a river. Would it be possible to pump such a slough dry?
3. How are springs formed?
4. Why is it dangerous to drink "run-off" water from ditches near settlements, even though the water may be quite clear?
5. Australia is a very old continent. The mountain ranges around the edge are worn down. The central desert is saucer-shaped. Can you account for the fact that artesian wells can be made almost anywhere in this desert? The wells, however, are usually very salt. Can you think of a reason for this?
6. What would be the effect on water storage if all the soil were washed away?
7. What prevents surface soil from being washed away?

Home Projects

1. Fill an empty tin with soil. Pour water into it until the soil becomes saturated.

Make a small nail-hole near the bottom of the tin. Does any water come out of the nail-hole? Does the water flow freely? Can you find any natural condition which could be explained by this experiment?

There may be a railroad cutting near your home. See if you can find in it an impervious layer of clay, hardpan or rock. Can you find any springs coming from the cutting?

2. At the beach or lakeshore dig a well in the sand. Account for the level of the water in it. Is the level higher or lower than that of the water outside?
3. Fill a large dishpan with sand, make hills and valleys, and then add water until the water table rises to form lakes. Explain why the level of the water does not depend upon the size or shape of a lake.
4. If there is a microscope in your school, bring some swamp water to school and ask your teacher to let you examine this water with the microscope.

Practical Applications of the Knowledge Learned in Chapter III

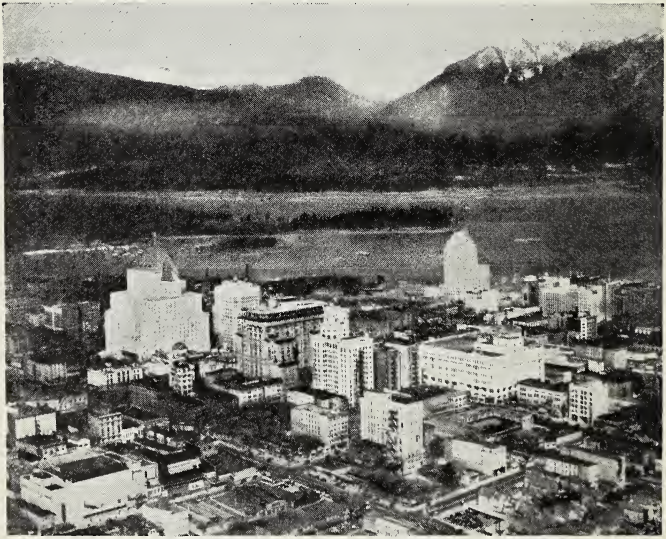
1. In reclaiming swampy land, that is, in making it suitable for farming, drainage ditches are dug very deep. Can you give a reason for this?
2. When a well goes dry, water may sometimes be obtained by digging the well deeper. Why?

CHAPTER IV

WATER IN THE HOME

Can you answer these questions?

1. From where does the water come which you use in your home?
2. Why do people not dig wells in cities?
3. What causes the water to gush from the faucet?



Courtesy Publicity Bureau, Vancouver

Fig. 14

The City of Vancouver has an excellent water supply. Its water is brought from the snow-covered mountains shown in the background.

The City Water Supply. If a city dweller desires a glass of water he turns on a tap and the water gushes out. How little effort is required! One seldom thinks of the careful planning that has been expended to provide the water. Before the water is supplied to the home many difficult problems have to be solved. The engineers must be sure of a year-round supply of water. If there are no natural reservoirs, such as lakes, rivers, or snow fields, artificial reservoirs have to be built to store the winter rains. In many cities water has to be brought from long distances through large mains or pipes. When water is used from natural lakes in populous districts it is likely to contain harmful germs. These must be destroyed before the water is safe for use. The water used in some cities contains sediment which has to be removed. When water is left in reservoirs it becomes flat and tasteless. It has to be made palatable and pleasant to drink. The problem of distributing the water to each house has to be solved. Besides these problems there has also to be solved the problem of removing waste water and sewage.

You may wonder why the city goes to such trouble and expense to secure water instead of allowing the citizens to dig wells in their own back yards, as is done in country districts. There are many reasons why wells cannot be used in cities. With so many people living in a small area it would be impossible to get sufficient water continuously. The water in the wells would be almost sure to become polluted by household waste and dangerous disease germs. Because of the large number of people in a city it is cheaper, safer and much more convenient to install a water system for the use of all.

Reserves of Water. Many cities are fortunate in having natural reservoirs close at hand, such as clean lakes, large rivers and snow fields.

The area from which a city gets its water should be uninhabited in order that there may be no danger of the pollution of the water. For that reason some cities have been obliged to secure their water from distant places. Even so, it has not

always been possible to obtain a natural water supply. Other cities have been put to the expense of creating reservoirs by building dams across rivers to make artificial lakes. When the country is flat it is not easy to make an artificial lake. In such a case it is necessary to dig one in the ground. Such an artificial lake has to be lined with clay or cement to prevent the stored water from seeping away.

Courtesy Montreal Water Board

Fig. 15.—A City Reservoir
Note the pumping station in the background.

Whenever possible the reservoir is located so that the intake, or entrance, to the water mains is higher than the highest point of the city. This allows the water to flow down hill to all parts of the city. Such an arrangement is called a *gravity system.*[1]

In a gravity system the water comes from all the faucets with force. This force is the result of the pressure of the water in the pipes. In order that there may be a ready flow from the faucets the pressure in the pipes must be kept up. Since pressure

[1] Gravity is the name of the force which causes all unsupported materials to fall toward the centre of the earth. It is the force of gravity which causes liquids to flow from higher levels to lower ones.

is so important in a water system you will be interested in doing an experiment to learn more about it.

PROBLEM

To find the cause of water-pressure.

Plan. If you were to hold a pile of books on your hand and remove them one at a time, the pressure of the books on your hand would become less. Can it be shown that water-pressure is caused in the same way; that is, by the weight of the water and the height at which the water stands?

Apparatus and Materials. Procure a tall oil can and some water (Fig. 16).

Method. Make a nail-hole in the side of the can near the bottom, another half-way up the side, and a third a few inches from the top. Cover the nail-holes with your fingers while a friend fills the can with water. When the can is full remove your fingers.

Observations. 1. From which hole does the water squirt farthest? 2. As the can empties what happens to the stream which comes from the lowest nail-hole?

Conclusion. 1. In which part of the can is the water-pressure greatest? 2. As the height of the water decreases what is the effect on the pressure at the bottom of the can? 3. Why should the pressure at the lowest opening be greater when the can is full than when it is only partly filled? 4. Has the weight of the water anything to do with the pressure? 5. Do you think that water would be forced out of any opening you might make in the can? What does the experiment tell you about water-pressure on the sides of the can?

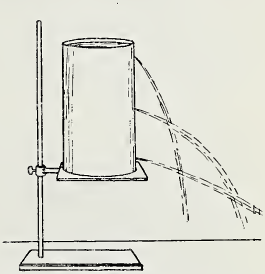


Fig. 16.—A Device to Demonstrate Water-Pressure

Why is the water-pressure greatest at the bottom of the can?

More About Water-Pressure. We have seen that as the height of the water increases the pressure on the walls near the bottom of the vessel also increases. This is due to the weight of the water. How do engineers take advantage of this pressure in a gravity water system?

PROBLEM

To discover the effect of water-pressure in the pipes of a gravity system.

Plan. We have seen, in our last experiment, that pressure at the lowest opening in the can of water is greater than at points higher up. Can

we show that the pressure at the lowest tap of a gravity system is greater than that of taps higher up? Let us make a model water supply system in which we can change the height of the outlet faucet at will.

Apparatus. A large vessel with an opening at the bottom (bell jar) to which a long rubber hose may be attached (Fig. 17). A pinch-cock and a glass nozzle.

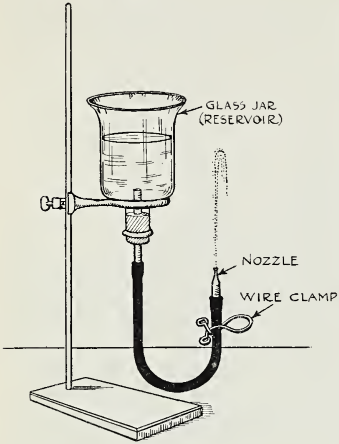


Fig. 17

What causes the water to squirt from the nozzle? How could the water-pressure at the nozzle be increased?

Method. Connect the hose to the bottom of the vessel. Fit the glass nozzle to the other end of the hose. Put a pinch-cock on the hose near the nozzle. Fill the vessel with water. 1. Hold the nozzle so that it is higher than the level of the water in the large vessel. Open the pinch-cock. 2. Hold the nozzle at the same height as the level of the water. Open the pinch-cock. 3. Hold the nozzle lower than the level of the water. Open the pinch-cock. 4. Repeat this, holding the nozzle a little lower each time.

Observation. 1. What happens when the pinch-cock is opened under the first condition? 2. When the nozzle is at the water level? 3. When the nozzle is at the lowest point? 4. How high is the water forced each time?

Conclusion. 1. What is the effect upon the water-pressure in the nozzle of increasing the difference between the height of the water level and the height of the nozzle? 2. Why does water not come from the nozzle when it is higher than the water level in the vessel? 3. In order to have water-pressure in a faucet where should it be placed with regard to the level of the water in a reservoir? 4. What determines the water-pressure in city water-mains? 5. What determines the height to which water can be forced from a fire-hydrant?

You can easily see that the position of the nozzle or its distance from the tank does not affect the *water-pressure* (i. e., the force with which the water flows from the nozzle). The pressure at the nozzle is determined entirely by the distance which the level of the water in the vessel is above the nozzle (see diagram).

In a gravity water system (Fig. 18) the level of the water in

the reservoir must always be higher than the highest faucet in the town in order to maintain the pressure which causes the flowing of the water. It is this water-pressure which makes it possible to send water through pipes over long distances. It also permits the placing of the faucets where they are needed.

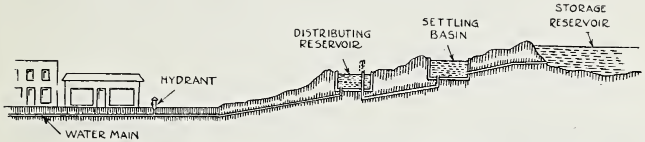


Fig. 18.—A Gravity Water System
Showing the "intake", settling basin, aeration plant, distributing reservoir and water mains to city streets.

In order to obtain enough pressure for these purposes the water intake is sometimes placed in distant hills. For example, the City of Los Angeles in California has established its reservoir and intake seventy-five miles away from that city. In other cases, the water has to be pumped. This occurs when the intake cannot be placed at a height sufficient to give the pressure which is needed. In order to get a greater pressure than the water mains can give, owners of tall buildings often build a water tank upon the roof. This gives the building extra protection in case of fire.

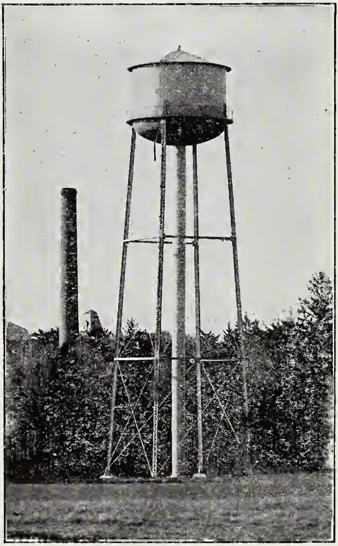


Fig. 19.—A Water Storage Tank

Purification of Water. The water supply of many cities often contains mud and other solid matter suspended in it. Before the water can be used for household purposes this suspended material must be removed. It is removed, sometimes, by allowing the water to stand in large tanks or "settling basins" where the suspended material settles to the bottom as sediment. Clear water is drawn from the tank. The sediment at the bottom of the tank must be removed from time to time.

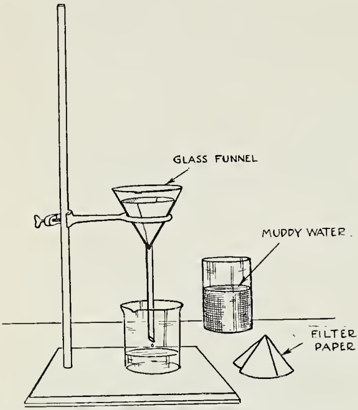


Fig. 20.—An Experiment to Show How Muddy Water May Be Filtered By Passing It Through Filter Paper.

Very fine particles of suspended material do not settle quickly enough to allow all the water to be cleared in settling basins. Water with very fine particles in it must be filtered. When water containing fine particles of suspended mud or sand is allowed to pass through porous material (Fig. 20), the sand and mud are filtered or strained out. Only clear water passes through the tiny pores. When, as in city water systems, a great deal of water must be filtered, the water is allowed to seep through beds of sand (Fig. 21). The sand beds or filter beds have to be renewed quite often. Why?

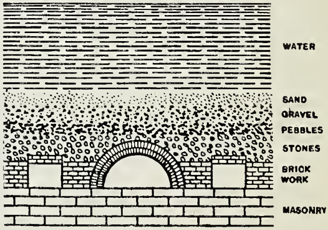
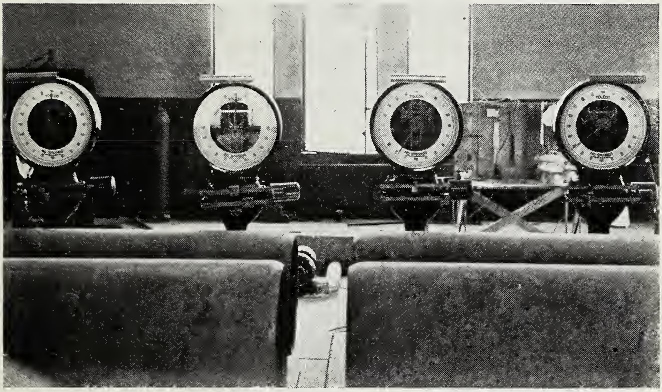


Fig. 21.—Cross Section of a Sand Filter

Sometimes the water contains bacteria which are dangerous to the health of the community. Before such water is safe it must be sterilized; that is, the bacteria in it must be killed. Sterile water does not contain any living germs. There are several ways of making water sterile. It can be made sterile by boiling it. It would, however, be impossible to boil all the water used in a large community and so other methods must be used. The most common method is to *chlorinate* the water (Fig. 22). A small



Courtesy Montreal Water Board

Fig. 22.—A Chlorination Plant

In the foreground are the one-ton cylinders of liquid chlorine which is used to sterilize the water. The scales regulate the amount of chlorine which is allowed to enter the water.

quantity of chlorine is put into it. This sets free chemicals which destroy the bacteria.

Drinking water, to be pleasant to taste, should contain small quantities of mineral salts as well as dissolved air. When water has been standing in a reservoir or a settling basin for some time it loses much of its dissolved air and becomes "flat" and tasteless. To correct this defect some communities install machinery to

force the water into the air in the form of a fine spray. This water spray absorbs air. It is then said to be *aerated.*

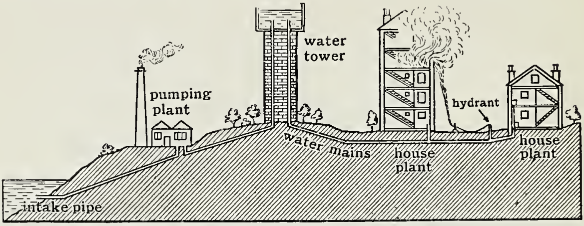


Fig. 23.—A Community Water System

When the source of water supply is not higher than the town the water must be pumped into storage reservoirs.

The problem of supplying a large city with water does not end with the building of storage reservoirs. The water must be distributed to the homes, factories, and other places where it is needed. To distribute it, water-mains must be laid along the streets. Smaller pipes must be laid to the houses. Hydrants must be installed near the street corners for use in case of fire.

Fig. 24.

How does water-pressure help the fireman?

Our cities are made beautiful by the aid of water. Fountains sparkle in the public parks. Drinking fountains are placed at convenient places to quench the thirst of the passer-by. Green lawns and beautiful flowers around the city home bring the breath of the country. All these things are made possible by the community water system.

Taking Care of the Waste. Body wastes and other waste material from our homes is called *sewage*. Unless sewage is quickly disposed of the health of the community suffers. Epidemics of disease soon spread in districts where sewage is allowed to accumulate. The community water system is of great value in helping to dispose of sewage, as by means of the water, the sewage can be flushed into large pipes called sewers. The sewers carry the sewage out to sea or to some lake or river where the water scatters it and makes it harmless.

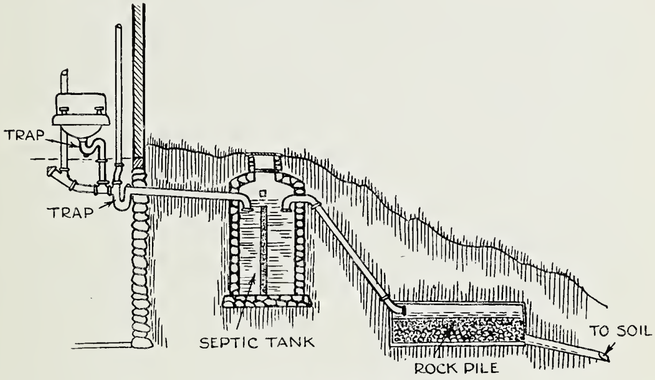


Fig. 25.—A Septic Tank

When there are no sewers, sewage is often disposed of by means of septic tanks.

When large amounts of water are not available sewage is disposed of by the use of septic tanks and cesspools (Fig. 25). In these certain kinds of bacteria which cause decay feed upon the dangerous sewage and render it harmless. The overflow water from the septic tank is allowed to filter through the ground and so becomes purified once more.

Guide Words

gravity system	reservoirs	outlet
water-works	suspended materials	intake
snow fields	chlorinate	faucet
bacteria	filter	purification
water-mains	sewage	absorbed
sediment	diverted	aerated
septic tank	sterile	disease germs
wells	mineral salts	sewers
water-pressure		

Signpost Sentences

1. It is unsafe to use water from .... in a city.
2. The water intake in a .... must be higher than the highest tap.
3. .... is due to the weight and height of the water.
4. Mud and other .... are removed by being allowed to settle in settling basins or by being filtered in sand beds.
5. .... are often destroyed by chlorinating the water.
6. .... water has no living germs in it.
7. Small quantities of .... make the water pleasant to taste or palatable.
8. Unless .... is properly disposed of it becomes dangerous to health.
9. Sewage is usually disposed of by flushing it through .... into large bodies of water where it becomes diluted and harmless.

Questions on Chapter IV

1. Why are not wells in general use in cities?
2. Why do cities sometimes secure their water supply from great distances?
3. How is suspended material removed from impure water?
4. How are bacteria destroyed in a city water supply?
5. What is the purpose of a septic tank?
6. Why are water storage tanks placed on the roofs of buildings?

Special Problems

1. What natural features of a countryside are necessary for the building of a dam?
2. Draw a map of the water supply system of the city in which you live.
3. Explain why the water-pressure is greatest at the lowest tap in a water system.
4. Find out, if you can, how the water-works system of your community is administered.
5. How would you sterilize your drinking water if you suspected that it contained disease germs?

Home Projects

1. If the source of the water supply of your city is close enough arrange for a visit to the intake. Make notes of what you see and prepare a report for the class.

2. If your city is provided with a pumping station pay it a visit. Note the manner in which the water is pumped, stored and distributed.

3. Secure a chart of the city water supply from the water-works department. Study it carefully and explain it to the class.

4. If you have an old water faucet at home take it apart and examine the parts. What would cause it to leak? You should learn how to repair a leaky faucet.

Practical Applications

Water motors on washing machines.
Hydraulic lifts.
Water turbines.
Hydro electric power plants.
Hydraulic mining.

Try to find out how water-pressure is used in each of these.

UNIT II

THE SOIL—ITS IMPORTANCE TO PLANT AND ANIMAL LIFE

CHAPTER V

THE SOIL

Can you answer these questions?

1. Why are the river valleys of India and China so thickly populated?
2. Will water ever run uphill?
3. Of what is the soil composed?

Fig. 26.
Soil and water make possible this prosperous country district.

4. Why are some soils more fertile than others?
5. What is alkaline soil?

Where People Thrive. A study of your geography will show you that the most thickly populated parts of the world are in those parts where the water is abundant and the soil is plentiful. In the great river valleys of Asia there are heavy rainfalls and deep soils. It is there that you will find the most thickly populated parts of the world. The Hwang Ho and Yangtse river regions of China and the Ganges river region of India are also very densely populated. The reason these river valleys have such dense populations is because fertile soil is plentiful there and water is abundant. People depend upon soil and water to produce their food. Soil is so important that modern governments are spending time and money on scientific studies to discover how the soil can be made to produce more food. These studies have shown that the fertility of the soil depends upon its composition. By studying its composition you can also learn what causes the soil to be fertile.

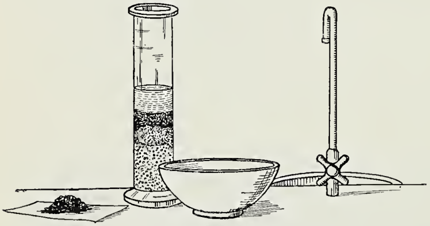


Fig. 27.
The different particles of which soil is composed can be separated by means of water. The heavier particles settle first.

PROBLEM

Of what is garden soil composed?

Plan. We have learned, in our studies of water, that the coarser particles of mud settle out first. Let us take advantage of this fact to separate the different parts of the soil.

Apparatus and Materials. A tall glass jar, a large bowl, a hand lens and a cupful of garden soil (Fig. 27).

Method. 1. Examine the soil through the lens. 2. Put a half cupful of the soil into the jar with a quantity of water and shake it well. 3. Allow the jar to stand for a minute. Pour the muddy water carefully into the bowl. Do not allow the sediment in the jar to escape. 4. Repeat this process until the water no longer remains muddy when shaken and allowed to stand. 5. Set the jar and bowl aside for several hours. When the

water in the bowl becomes clear pour it off. 6. Allow the sediment to dry. 7. Pour the water off the sediment in the jar also.

Observations. 1. Could you detect different materials in the soil by means of the lens? 2. Is there any difference in the appearance of the sediments in the jar and in the bowl? 3. In which are the coarse gritty particles? In which the fine? 4. Rub between your fingers a little material taken from each of the deposits. Do they feel alike? Examine each with the lens and note differences in the colour, size and shape of the particles.

Conclusion. Are the particles which compose soil all alike? How many different substances did you discover? What substance was most abundant in the residue in the tall jar? What substance was most abundant in the residue in the bowl?

The two substances most easily recognized in the soil are sand and clay. Clay is usually white or grayish. But this clay is dark and discoloured. The material that makes it dark is called *humus*. Humus in the soil comes from decayed vegetable and animal matter. The leaves, the twigs and other parts of plants decay and produce humus. In a similar way animal materials decay and form humus. All materials which are formed by plants or animals are called organic materials. Humus, therefore, is an organic substance. Organic substances always contain carbon, a substance which can be burned.

PROBLEM

Does the soil contain organic matter?

Plan. If the dark substance in the clay is organic it can be burned away and the clay will show up in its true colour.

Apparatus and Materials. A deflagrating spoon (an ordinary iron spoon will do); some of the clay residue of the last experiment; a bunsen burner or a spirit lamp (Fig. 28).

Method. Put a small quantity of the clay into the spoon and heat it to a red heat for some time.

Observations. 1. Did the soil glow when it became red hot? 2. Did any of the soil disappear? 3. Did it change colour after being heated?

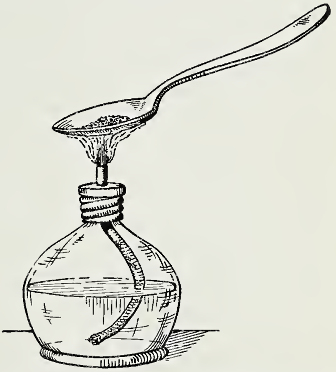


Fig. 28.—A Demonstration to Show That Soil Contains Humus

Conclusion. Was there any organic material (humus) mixed with the clay?

These experiments show us that the three chief substances in garden soil are clay, sand and humus. A soil of this nature is called *loam*. If the loam is mostly sand, it is called a *sandy loam*. If there is a great deal of clay in it, it is called a *clay loam*. The proportion of sand or clay plays a very important part in the usefulness of the soil.

One of the many uses of soil is to absorb the rain-water and hold it for future needs of plants. Which type of soil is best suited to absorb and hold water?

Problem

Which will retain the most water: pure clay, pure sand or sandy loam?

Plan. If equal quantities of water are poured into equal amounts of the different soils the one which can retain the most water could be discovered.

Apparatus and Materials. Three glass tubes about one inch in diameter and open at both ends, three pieces of cheese cloth, three elastic bands, some clay, some sand and some loam soil.

Method. 1. Cover one end of each tube with a piece of cheese cloth held in place by an elastic band. 2. Fill one tube to a height of two inches with finely powdered dry clay. 3. Fill the second tube to the same height with dry sand and the third with dry garden loam. 4. Pour a measured quantity of water into each tube. 5. Catch, in separate beakers, all the water which trickles through (Fig. 29).

Observations. 1. Through which tube did the water pass most freely? 2. Through which did it pass with greatest difficulty? 3. Was the amount of water in each beaker the same at the end of the experiment?

Conclusion. Which soil retained the most water? Which the least?

We learn from this experiment that clay loam is the kind of loam which will retain the most water. In parts of the country where there are prolonged dry spells, clay loam is the best kind of soil for gardens. In a wet climate, clay loam holds too much water and becomes soggy. Such wet soil is likely to become sour. It is also not suitable for gardens because the excess of water prevents air from reaching the roots of the plants.

Water Runs Uphill. You have learned that during dry seasons the water table becomes lower and is often far below the

deepest roots of growing plants. The plants, however, continue to grow and thrive. This shows that in some manner they are getting water from the water table. If you were to remove the dry surface soil you would notice that the soil below is quite

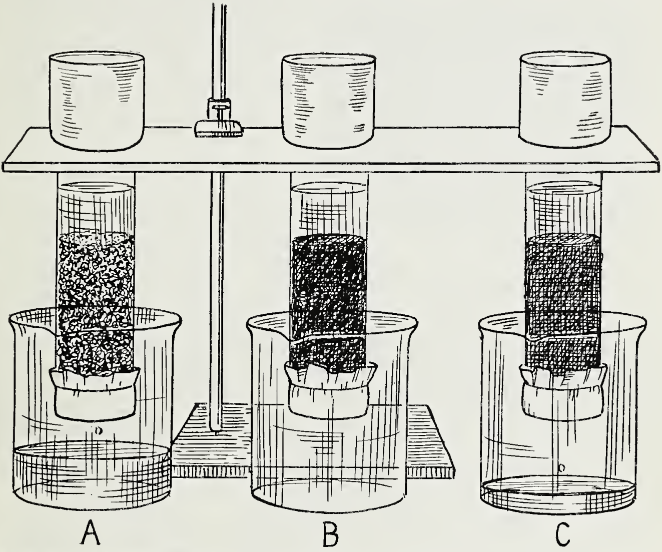


Fig. 29.—An Experiment to Discover Through Which Type of Soil Water Passes Most Quickly

A contains sand, B contains clay and C contains garden soil. Equal amounts of water are poured into each.

damp even though you would have to dig many feet to reach the water table. How does the water travel upwards through the soil? Does it flow upwards? Water usually flows downwards. Can you find an answer to this question?

Problem

What causes water to move upwards through the soil?

Plan. We know that the particles of soil are packed closely together.

We have seen, however, that water soaks downwards through the soil. There must then be spaces between the particles (Fig. 30). Have these spaces anything to do with the upward movement of the water? Does the size of the spaces have any effect upon the movement? Let us see if small spaces have any effect upon the upward movement of water.

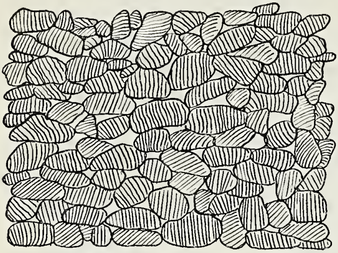


Fig. 30.
Soil is made up of particles with air spaces in between the particles.

Apparatus and Materials. Two pieces of glass about three inches square (Fig. 31). Four or five capillary tubes ("Capillus" is a Latin word meaning "hair"). One tube should have a bore about the diameter of a hair. A saucer of water. The water should be coloured by a few drops of ink, so that it may be seen more easily.

Method. 1. Place the two squares of glass evenly together and dip an edge in the saucer of water. 2. Squeeze the two plates tightly together. 3. Stand the capillary tubes in the saucer of water.

Observations. 1. Did you observe anything unusual? 2. Did the water rise between the glass plates? 3. Did squeezing the plates tightly together have any effect? 4. Did the water rise in the glass tubes? In which one did it rise to the greatest height? In which one did it rise the least?

Conclusion. Will water rise in the space between two surfaces held closely together? Will water rise in a capillary tube? Does water rise to greatest height in the smallest capillary tube? Will water rise higher if the space is smaller between surfaces?

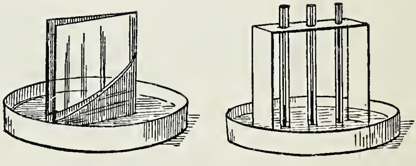


Fig. 31.
A. Water rises between two glass plates held together. B. Water rises in capillary tubes.

The above experiment leads us to conclude that water will rise between two surfaces that are close together. The closer they are together the farther the water will rise. Since the fact that water will go uphill in this manner was first noticed in connection with glass tubes of very fine bore (hair-like bore) we call the process *capillarity*. We say water rises in fine tubes by capillary

attraction. It is the attraction between the walls of the tubes and the surface of the water that causes the water to rise. It is this same force of capillarity that causes water to rise from the water table to the roots of the plants.

We saw that water rises better between surfaces that are very close to each other. For this reason water rises better in tightly packed clay soil than in sandy soil where the particles are loosely packed. A clay loam soil will furnish more water to the plants than a sandy loam. However, the clay loam is likely to draw such a quantity of water to the surface that much of the water is lost by evaporation and the underground supply becomes used up. To conserve or save the underground water in such soil, farmers "cultivate" or break up the surface. The loosening of the surface prevents the water from coming to the top but still allows the roots to get a plentiful supply (Fig. 32).

Soil contains a great many materials besides clay and sand. A good garden soil must have in it the salts that plants need for their growth. A few of these are salts containing iron, nitrogen, sulphur, phosphorous and potassium. They are called mineral salts. Ordinary table salt is a mineral salt. To be of use to the plant the salts must be soluble in water.

Alkaline Soils. Good garden soil contains the amounts of mineral salts necessary for plant growth. If there are not enough mineral salts in the soil they must be supplied to it in the form of fertilizers. Sometimes there may be too much mineral salt in the soil. In some parts of the Canadian prairies the soil contains too much mineral salt. These soils are *alkaline*. They contain alkaline salts. A familiar example of an alkaline salt is washing soda, which when dissolved in water makes the water soapy to taste and slippery when rubbed between the fingers. There are other alkaline salts. They all act in a similar way. By means of red litmus paper[1] scientists can recognize alkaline salts and alkaline substances. Secure a piece of red litmus paper and dip it into water in which washing soda has been dissolved.

[1] A kind of litmus paper can be made by soaking blotting paper in the juice of a red cabbage.

Notice that the red litmus paper is turned blue. All alkaline substances will turn red litmus paper blue in the same way. In some regions the alkaline salts are so abundant that they hinder the growth of plants.

Fig. 32.—Dry Farming

The soil is being mulched or loosened to check capillarity. How does this help to conserve the underground water?

Acid Soil. Sometimes soils contain *acid* and are called acid soils. Acids are sour to taste: vinegar, lemon juice and sour milk contain acids. Scientists recognize acids by their action on blue litmus paper. Acids turn blue litmus paper red. Wet, soggy soils are apt to contain acids because the water dissolves acid-forming gases which are given off by plants. Such soils are called "sour" soils. Very few plants thrive in sour soil. The gardener, or the farmer, can remove acid from the soil in two ways: he may

drain the soil or may put lime into it. The lime forms an alkali. When an alkali and an acid are mixed in the proper proportions the result is neutral—neither alkali nor acid.

Some of the salts necessary for plant growth are called *nitrates*. These nitrates are formed by the decay of organic material. The humus which is so necessary in good garden soil is the chief natural source of nitrates. When there is very little humus in the soil, there will not be enough of the nitrates. These nitrates must be supplied in some way. Humus could be put into the soil if it could be obtained. Often, however, some fertilizer containing nitrates is used. This supplies what was lacking in the soil and makes it fertile.

In Chile are found large deposits of nitrates. These deposits are mined. The nitrates are shipped to all parts of the world as Chilean saltpetre. A great deal of this salt is used as fertilizer.

Other chemicals that furnish nitrates when put in the soil are produced as "by-products" of industries. Gas manufacturing produces ammonium sulphate as a by-product. Phosphates are produced as a by-product in the smelting of mineral ores. The Western Canadian farmers are beginning to use the phosphates produced in the great smelter in Trail, B.C.

Guide Words

fertile	alkaline	vegetable matter
hand lens	sand	capillarity
sediment	clay	mineral salts
cultivate	humus	organic
filter	loam	fine bore tubes
acid	nitrates	

Signpost Sentences

1. Human population is dense where the soil is ....
2. A good garden soil should contain clay, sand, humus and ....
3. .... is formed from decayed plant and animal matter.
4. .... loam will hold more water than sandy loam.
5. .... causes water to rise through the soil.
6. Alkaline soils contain an excess of ....
7. A wet soil often becomes ....

Questions on the Chapter

1. Why are the river valleys of India and China so densely populated?
2. What two necessary things must be in abundance before a community can grow?
3. What substances are found in garden soil?
4. How can you detect acid in the soil?
5. How can you detect alkali in the soil?
6. How do plants get water during a dry summer?
7. How does the gardener prevent loss of water from the soil?

Problems on Chapter V

1. What causes oil to rise in a lamp wick?
2. How does a blotter soak up ink?
3. Why does the underside of a board soon become damp when it is laid on "dry" ground?
4. How can you tell without tasting it that a substance contains alkali?

Special Problems and Practical Applications

1. Explain how cultivating the soil helps to conserve the underground water.
2. Explain why alkaline soils are found in desert regions.
3. Show how the type of soil in your locality helps to determine the kind of plants which grow there.
4. Are there any mineral salts which are necessary for plant growth lacking in your locality? What kind of fertilizers do the gardeners in your neighbourhood use?
5. Fruit trees require large quantities of water. What type of soil is best suited to them?

Home Projects

1. With the aid of litmus paper try to discover around your home five alkaline and five acid substances.
2. Make some litmus paper for yourself by soaking the juice from a red cabbage leaf in blotting paper.
3. Examine soils in different parts of your neighbourhood and classify them as loam, clay loam, or sandy loam.

CHAPTER VI

THE SOIL FACTORY

Can you answer these questions?

1. Are the shiny flakes in a piece of granite gold?
2. From where does clay come?
3. What is igneous rock?
4. How did the soil become so evenly distributed over the great stretches of prairie?
5. Does soil reach to the centre of the earth?
6. When rocks are worn away what becomes of them?

The Rock Mill. You have learned that the soil is composed chiefly of sand and clay. You have examined the soil with a lens and found the sand and clay to be composed of very small pieces of rock. By what means have rocks been ground up into such tiny particles?

If you wished to smash up a rock into pieces small enough to form the little grains of soil you would require an anvil and a heavy hammer. You might pound for hours and have but little soil to reward your efforts. But everywhere there is soil in abundance. All this soil, at some time in the past, was ground from rocks. What were the mighty forces which ground up the rocks and formed soil? Are these forces still at work?

Formed by Fire. To answer these questions we must know something of the nature of the world itself. Our world is a sphere about 8,000 miles in diameter. Its surface was, long ago, white-hot and melted or *molten*. As time passed it cooled and much of the white-hot material hardened and formed a crust of rock. As it continued to cool it contracted or became smaller. The hot interior contracted more than the surface crust. As a result this surface crust no longer fitted evenly over the

material below it. Consequently it folded into huge wrinkles. Our present mountain ranges came from these wrinkles. The rocks which were formed from the hardening of the molten material are called *igneous* rocks (the Latin word "ignis" means "fire"). All rocks which are formed by the action of heat are called igneous rocks.

There are many kinds of igneous rocks. The most common in Canada is granite (Fig. 33). It is usually a greyish rock speckled with black. Sometimes it is stained by minerals which are dissolved in it. Copper gives it a greenish colour and iron rust a reddish colour.

Courtesy Geological Survey of Canada

Fig. 33.—Photograph of Granite

Granite is a common igneous rock. It is a mixture of quartz, feldspar and mica. Examine a piece of granite. Can you identify these three substances?

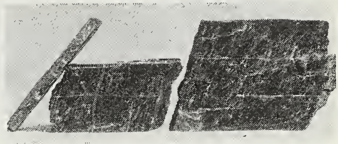
Examine a piece of granite and you will find it to be composed of small crystals. There are three distinct kinds of crystalline substances found in granite. These are quartz, feldspar and mica.

Quartz. Quartz is often found alone in the form of six-sided crystals (Fig. 34). These crystals are usually clear and transparent like glass. Sometimes they are coloured by small amounts of minerals. Such coloured crystals are prized as jewels. Onyx, cornelian and amethyst are coloured quartz crystals. Quartz is also found in large, milky coloured veins. Gold, silver and lead are sometimes mixed with it. A dark variety of quartz,

called flint, will break with a sharp edge. In ancient times our forefathers shaped flint into arrowheads, knives and hatchets.

Fig. 34.—Quartz Crystals
Pure quartz crystals such as these are sometimes called rock crystals.

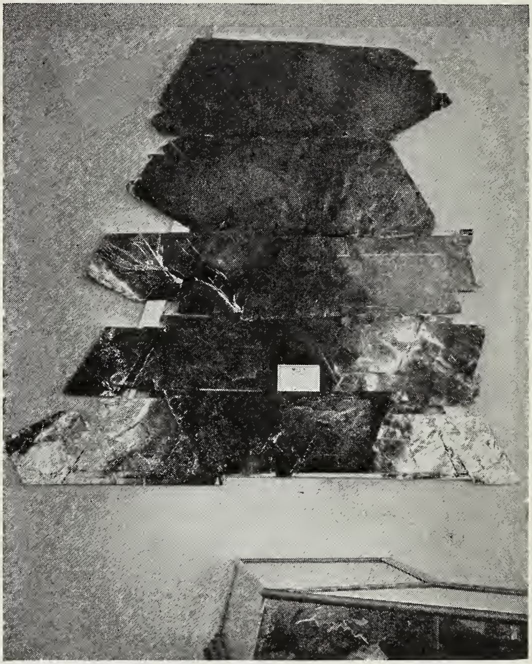
Feldspar. When feldspar is found in a pure state it is also crystalline (Fig. 35). It will break up into regularly shaped blocks with shiny surfaces. Feldspar is nearly as hard as quartz but it is not so durable. An acid-forming gas, carbon dioxide, which is found in the air, changes feldspar into a white powder called "kaolin." Kaolin is the clay used in the manufacture of fine china and pottery. When it is baked in a hot oven, the clay particles fuse, or melt together. From kaolin, aluminum is extracted by means of an electric current.



Courtesy Mines Branch, Dept. of Mines, Ottawa
Fig. 35.—Feldspar

Mica. The third substance found in granite is mica. If you

examine the piece of granite again you will see in it tiny flakes of mica shining like gold. Mica is sometimes found in a pure state (Fig. 36). It can be split into thin, transparent sheets.



From Bruce's Mineral Deposits of the Canadian Shield

Fig. 36.—Mica

Mica sheets are used in stove doors and in such electrical fittings as fuse plugs and toasters. It will not burn, nor will it conduct an electrical current. It cannot be destroyed by heat.

Attacked by Acid. By what natural processes have these igneous rocks been broken up so that they form soil? Since many

of our mountain ranges are composed of granite it is clear that much of our soil has come from the decomposition or breaking up of granite. Granite is very hard. It is used for foundations of lofty buildings. Yet it will decay. We have already noted that feldspar crystals are broken up by carbon dioxide and water. The carbon dioxide attacks the feldspar of the granite. If you

Fig. 37.—Map of the Great Ice Sheet of North America

search among granite rocks you may find a piece of "rotten" granite. It will crumble away in your hand and leave your fingers covered with a white powder, which is kaolin or clay. The coarse particles in the rotted granite are quartz and mica crystals, and these form sand. Thus we see that the carbon

dioxide of the air is slowly changing the granite mountains into clay and sand. Clay and sand in turn are the greatest part of the soil.

Water the Master Worker. In addition to the action of the carbon dioxide of the air there are other natural forces which break up granite and other rocks. You know that when water freezes it expands. If water is allowed to freeze in the water pipes it often breaks them. As freezing water is expanding it exerts a great pressure, and so when it freezes in the cracks of the rocks the cracks are widened, and pieces of rock are chipped off. Running water wears away these pieces by causing them to grind each other until they are worn smooth. The smaller pieces become gravel and finally sand and clay. You have noticed that the rocks in a stream are always rounded. In a similar manner the rocks along the sea shore are ground into pebbles and sand by the waves and tidal currents.

Fig. 38.—A Glacier-Scored Rock
(Photo by G. S. Sweeting of specimen in the Geological Collection of the Imperial College of Science.)

Glaciers. Glaciers play a part in grinding rocks into soil. Glaciers are formed by the accumulation of snow and ice in regions where the summer temperature does not rise sufficiently to melt all the winter snow. Year after year the snow piles up and hardens into ice. The added weight of the new snow each year forces the ice to move down to warmer regions where it is melted. Greenland is, at present, covered by a huge glacier. Canada too, at one time, was covered by glaciers (Fig. 37). As a glacier moves slowly along, rocks become embedded in the ice of which it is composed. Under the enormous weight of the glacier the embedded rocks grind and scour the surface rock over which the glacier moves (Fig. 38).

The Wind. You have seen workmen engaged in cleaning a

stone building by a sand blast. By means of compressed air they blow sand against the walls of the building. The hard, sharp grains of sand cut away the soiled surface of the stone. Similarly, in dry countries, strong winds drive particles of sand against the rocky mountain ridges and gradually wear them down (Fig. 39).

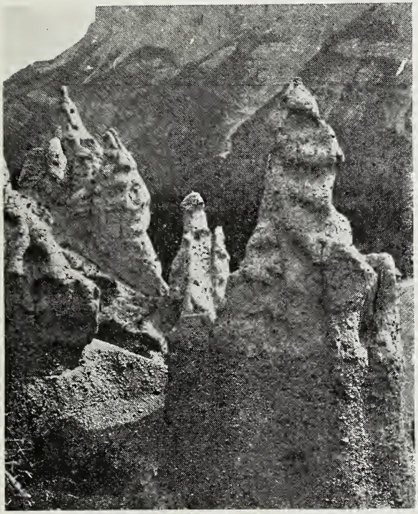


Fig. 39.—Hoodoos, Banff, Alberta
The wind carved these oddly shaped pinnacles.

All these forces—the wind, water, frost, ice and carbon dioxide—wear away the rocks. We say that they *erode* the rocks. The wearing away of rocks is called *erosion*.

Animal Helpers. The earthworm plays a part in the making of soil. As it burrows into the ground it grinds, in its gizzard, the coarser particles of sand. It carries the humus down deep into the soil to the roots of the plants. The burrows which it digs permit the circulation of air through the soil. Plants cannot grow well unless their roots are supplied with air. Larger animals, too, play a similar part. Small stones are ground up in the gizzards of birds. The excreta from animals help to form the humus of the soil.

Sand and clay by themselves do not make fertile soil. Humus is necessary. Humus becomes a part of the soil by the decay of vegetable and animal matter.

Delivered to the Farm. Soil is made as a result of the erosion

of rocks. The great mountain ranges are the chief sources of soil. In the mountains there are rapid changes in the weather. Because in the mountains so much rock surface is exposed to the action of the weather, erosion takes place very rapidly there.

A young student of science living in Saskatchewan or Manitoba, hundreds of miles from the nearest mountains, might wonder how the soil has travelled so far to his neighbourhood and how it has been spread out so evenly. The great carrier and distributer of soil is water. As the torrents pour down the mountain canyons they carry into the larger streams the particles of eroded rocks—the sand, the clay, the pebbles. Finally, the rivers carry the soil particles into lakes or into the ocean. Also in seasons of flood many rivers overflow their banks. Before the flood subsides the soil particles settle over the land in an even layer. This layer of deposited soil is called *silt*. The silt deposit becomes deeper after each flood season until a thick, rich soil is built up. Such soil is called *alluvial* soil. The rivers, however, carry most of the soil into lakes and ocean. At the mouth of each river where the flow of water slackens the coarser particles of silt usually settle out and form triangular-shaped deposits called *deltas*. Delta soils are fertile.

The Foundations of a Country. Some of the soil particles are so fine that they do not easily settle from the water. They are carried out to sea by the tides and ocean currents. When they do settle they become mud or ooze upon the bed of the oceans. The fine clay soil of the prairie provinces was laid down in this manner. Many thousands of years ago, the prairie land was ocean bottom. In that distant time large rivers carried soil made of eroded rocks from the Laurentian and Appalachian mountains into the great, shallow ocean which existed where the prairies now lie. The silt which was deposited kept accumulating until it reached the surface of the water and formed large areas of marshy land. Years afterwards the marshes became dry. In this way the prairie lands were formed. Why did the marshes become dry?

Earth Convulsions. In the course of time the buckling of the earth's crust slowly thrust the mountain ranges higher. The ocean beds were raised at the same time until the muddy ocean

Courtesy Smithsonian Institution

Fig. 40.—A Glacier Showing Boulders and Soil Which It Has Carried Down From a Mountain

bottom became dry lands. The deep, stoneless soil of the level prairies was formed in past ages by the erosion of the jagged,

rocky peaks of the Laurentian and Appalachian mountains. These mountains are no longer steep and rugged. Their tops have been worn low and rounded. They were eroded and the silt from them formed the fine fertile soil of the Great Central Plain. In ages to come the silt which is now collecting on the bed of the ocean will form the soil of new continents which are still unborn.

Glacier Transportation. Much soil has been brought from distant mountains by the slowly travelling glaciers. As a glacier moves along it carries with it all the loose material in its path. When the glacier melts the loose material is left in deposits. Glacier-transported soil is usually a jumbled mixture of soil, boulders and gravel (Fig. 40).

Soil which is deposited by rivers and glaciers is called transported soil. Some rocks, however, merely decay and form soil which replaces the rocks. Such soil is called *residual* soil (Fig. 41). Decay of limestone deposits is a common source of

Fig. 41.—Residual Soil Being Formed By the Decay of Limestone Rock

Why are the finer particles of soil near the surface?

residual soil. The growing roots of trees helps to make residual soil by breaking the rocks (Fig. 42). The action of carbon dioxide given off by the roots of plants promotes the decay of

the rock. Such residual soils are finer at the surface where they receive the most "weathering". The particles become coarser and coarser as one digs deeper. As a rule residual soils are not very fertile because they are formed from one kind of rock only and so are likely to lack some of the elements needed for plant growth.

Fig. 42.
Trees help to form soil by splitting rocks.

These natural forces which have made soil in the past are still operating. Silently and slowly natural forces are still grinding up rocks the world over. The increase in the amount of soil made each day can scarcely be noticed. Yet, because erosion has been going on for countless ages, silt has been accumulating until, in some places, it has become miles deep.

Guide Words

igneous	flint	alluvial
granite	kaolin	delta
quartz	glaciers	transported soil
feldspar	silt	residual soil
decomposition	frost	layers
mica	sediment	erosion
rocks	water	wind

Signpost Sentences

1. Soil is formed by the .... or breaking up of rocks.
2. .... contains quartz, feldspar and mica.
3. The carbon dioxide of the air forms an acid with water. This acid changes .... into .... or clay.
4. The .... and mica crystals become sand when granite decays.
5. .... are broken up by frost, water, ice, wind and animals.
6. Soils are transported by (a) ...., (b) .... and (c) ....
7. Soils are deposited as .... on lake bottoms and on the ocean bed.

Questions on Chapter VI

1. What are the three chief materials found in granite?
2. What is the chief substance in the air which causes granite to "decay"?
3. What metal is extracted from clay?
4. Why are the oldest rocks in the world igneous?
5. How do each of the following help in soil-making (a) freezing water, (b) running water, (c) glaciers, (d) wind, (e) animals?
6. How are deltas formed?
7. How can you identify a glacier-deposited soil?

Special Problems and Practical Applications

1. Is the soil in your locality residual, glacier-deposited or water-deposited?
2. What evidences have you that the land where you live has been under water?
3. Of what is glass made? Read an account of glass making and report to the class.
4. How are bricks made?
5. Near the coast of Holland the ocean is very shallow, the ocean bottom is covered with silt which could become fertile soil. How do the Dutch people make use of it?
6. Do you know of any place where the ocean bed is reclaimed for farming purposes?
7. Do you know of any part of Canada which is reclaimed soil?
8. Shallow lakes are often drained to "reclaim" the fertile soil which has accumulated in them. Do you know of any?

Home Projects

1. Collect specimens of granite, limestone, clay, mica, quartz, feldspar, and as many other kinds of rocks as you can identify.
2. Learn to distinguish between quartz and marble by putting acid on each of them.
3. Examine the buildings in your nearest city. Find out the kinds of rock used in their construction.

UNIT III

THE AIR AND LIVING THINGS

CHAPTER VII

THE CHEMISTRY OF THE AIR

Can you answer these questions?

1. How do you know that air exists?
2. Of what materials is air composed?
3. Can air be made artificially?
4. Will a fire burn without air?
5. Why does a fire burn more brightly when it is fanned?

Air—the Invisible Part of Your Environment. Before a student of science can make much progress in his studies he must understand his surroundings or environment. You will recall from Chapter I that the scientist is able to show that air is a real substance. The experiment which he used to show that air is real and that it occupied space has enabled man to build *caissons*. Caissons enable him to build bridges. Without experiments which lead to knowledge of the environment such bridges would never have been built.

Air is a part of your environment. It is all about you. It has important effects upon your life. You should learn all you can about it. You can learn about it by experimenting with it.

To begin, you yourself can tell something about the air. You have experienced violent wind storms. You have seen trees bent and broken by the force of the wind.

Wind is used to drive windmills and sail-boats. It has been harnessed to work for man. Wind is moving air. You can set

air in motion by beating against it with a fan. You can feel the air by merely waving your hand.

Air and Fire. Have you ever fanned fire to make it burn more brightly (Fig. 43)? The fanning caused more air to move into the fire. Have you noticed that the kitchen fire burns more brightly when you open the draughts, or that a fire may be put

Fig. 43.
Why does a fire burn more brightly when it is fanned?

out by smothering it or covering it so that air is prevented from reaching the burning fuel? Your observations will have lead you to guess that air has much to do with burning. You can experiment to see how necessary air is to keep fires burning.

PROBLEM

Is air necessary to keep fires burning?

Plan. If you place burning candles in closed vessels which contain different amounts of air you will be able to learn:

(a) Whether candles go out after the air supply is shut off.

(b) Or whether the amount of air in the vessel plays any part in the length of time the candle will continue to burn.

Apparatus and Materials. Two wide-mouthed bottles, one large and one small. Two cover glasses to place over the bottles. Two short candles (Fig. 44).

Method. Melt the end of each candle and fasten it to the bottom of a bottle. Light the candles and allow them to burn. Cover both bottles at the same instant.

Observation. 1. Did the candles burn freely in the open jars? 2. Did they go out immediately when the cover glasses were placed on the jars? 3. In which jar did the candle go out first?

Conclusion. 1. Can you explain why the candle in the larger jar continued to burn after the other had gone out? 2. Why did the candles remain alight when the cover glasses were off? 3. Why did both candles finally go out?

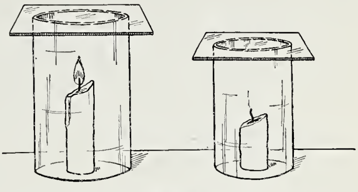


Fig. 44.
Why did the candle in the smaller jar go out first?

From this experiment we conclude that the burning of the candle flame depends upon a continued supply of air. The candle which had the most air burned the longer period of time. When air was allowed to reach the candle freely you found that the candle burned without difficulty. It would have burned until the candle was all gone. You discovered that a fire will go out or become *extinguished* when the air supply is shut off.

We say that air supports *combustion.* Combustion means burning. Without air there would be no combustion. The fact that the amount of air in a closed jar determines how long a candle in it will continue to burn suggests to you that air or a part of it is used up as a candle burns. If this is true a lighted candle when lowered into one of the jars you have just used, should go out. Try the experiment yourself. Light a candle, fix it to the end of a wire. Remove the cover glass and lower the candle into the jar (Fig. 45).

You will find that the lighted candle becomes extinguished. Evidently the part of the air in the jar which supports combustion had been used up and the remainder was not able to support combustion.

A Burning Candle Produces a Gas. You know that air is everywhere about you. If the air was all used up in the jar

more air would have gone into the jar when we lifted the cover. You know that the air did not go into the jar because the candle did not burn there. Some other invisible gas must have been in the jar and this prevented the air from entering it. Was this gas produced by the burning candle? An experiment might answer the question.

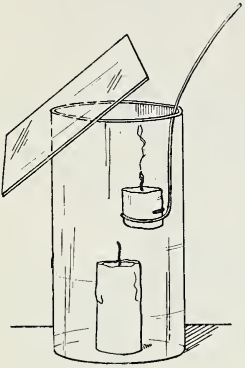


Fig. 45.
Explain why the second candle is extinguished when it is thrust into the jar.

Take one of the jars you have already used and wash it. Pour a small quantity of lime-water into the jar and shake well.[1]

You will not notice any change in the appearance of the liquid. The air in the jar has no noticeable effect upon the lime-water. Now pour a little lime-water into the jar in which the candle has been burned. Shake it well. This time the lime-water turns milky in appearance. Evidently the burning candle must have produced a gas which turned the lime-water milky. Repeated tests have shown that there is only one gas which will turn lime-water milky. It is the gas *carbon dioxide.* You have discovered therefore that when a candle burns it produces an invisible gas, carbon dioxide. Carbon dioxide is produced when any substance containing *carbon* is burned in air.

What is Carbon? Carbon is found in many materials. Carbon by itself is usually black. We find it in nearly all fuels. When it is combined or joined chemically with other substances it does not appear black. Carbon is a part of such substances as wood, paper, cloth, coal, gasolene and illuminating gas. It is

[1] You can make lime-water very easily. Shake a little lime in water. To do this, place a piece of quicklime about the size of an egg in a jar of water. The lime becomes heated and the water bubbles. Allow the water to stand a few days until it becomes clear. Pour off the clear water. It is *lime-water.* Lime-water is water which has a small amount of slaked lime dissolved in it.

a part of all organic matter (see pp. 43). The following experiment will show that there is carbon in wood.

PROBLEM

Can you show that wood contains carbon?

Plan. Many substances which contain carbon also contain gases combined with the carbon. These gases may be driven out of these substances by heat and the black carbon will then be seen.

Apparatus. Hard glass test-tube; wood chips; bunsen burner; one-holed stopper with glass tube to fit (Fig. 46).

Method. Place the chips in the test-tube and insert the stopper. Heat the test-tube in the bunsen flame.

Observation. 1. What happens to the wood as the test-tube becomes hot? Do you see anything being driven out of the wood?

Conclusion. 1. How do you know that wood contains carbon? 2. Carbon will burn. Why did it not burn in the closed test-tube?

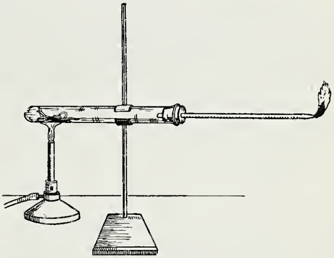


Fig. 46.

When wood is heated in a test-tube it becomes charred. As it chars a gas is driven off. This gas will burn in air. The black material in the test-tube is almost pure carbon.

The black material remaining in the test-tube is called *charcoal*. It is almost all pure carbon. By placing cloth, sugar, starch or meat in the test-tube you could have seen that they too contain carbon.

A great many substances which contain carbon do not char or become black as wood does because they evaporate or change into a gas when heated. Some of these substances are gasolene, coal oil, alcohol and paraffin or candle wax. We know that these materials contain carbon because when we burn them the gas carbon dioxide is produced. Carbon dioxide always contains carbon.

Carbon Dioxide Can Be Produced from Chemicals. You have learned that carbon dioxide may be produced when carbon, or any organic substance which contains carbon, is burnt.

Can this gas, carbon dioxide, be produced in other ways than by burning carbon? Scientists have learned that carbon dioxide can be set free from many different substances. The next experiment shows you how to do this.

PROBLEM

To prepare pure carbon dioxide from other chemicals than carbon.

Plan. Marble contains carbon dioxide. This carbon dioxide can be liberated or set free from the marble by the chemical action of an acid which is poured on it. Pour acid on marble and collect the gas produced.

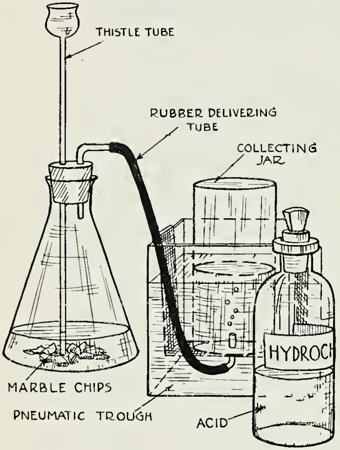


Fig. 47.—How to Prepare Carbon Dioxide

Apparatus and Materials. An erlenmeyer flask; a two-holed stopper to fit the flask; a thistle tube; bent glass tube; rubber delivery tube; pneumatic trough; several collecting jars; glass covers; a quantity of marble chips and some hydrochloric acid (Fig. 47).

Method. Put the marble chips into the erlenmeyer flask. Set up the apparatus as shown in the diagram above. Pour the acid down the thistle tube. By displacing water, collect the gas produced in the collecting jars.[1]

When you have several bottles of gas collected remove them by placing a cover glass over the mouth of each jar. Set them upright on the table. Do not remove the cover glass until you are ready to test the gas.

Into one of the jars pour a little lime-water and shake it up. Light a candle and lower it into the next jar. Next place a lighted candle in a collecting jar containing ordinary air. Pour carefully the contents of the third bottle of gas into the jar containing the lighted candle (Fig. 48).

Observation. 1. Did the gas turn the lime-water milky? 2. What happened to the burning candle which was lowered into the jar containing

[1] To collect a gas by displacing water first fill the jar with water. Put a cover plate over the jar and place it mouth down in the water in the pneumatic trough. Remove the cover plate. The water will stay in the jar. If the delivery tube is placed beneath the mouth of the jar bubbles of gas will collect in the jar and so push out, or displace, the water.

the gas? 3. What happened to the burning candle when the gas was poured into the jar holding it?

Conclusion. 1. Was the gas carbon dioxide? 2. Does the gas support combustion? 3. Is carbon dioxide heavier or lighter than air?

You have learned from this experiment that the gas carbon dioxide can be produced chemically by the action of an acid upon marble. You have also learned that it is an invisible gas heavier than air and that it will not support combustion. The gas produced by the burning candle also turns lime-water milky, and so it, too, must be carbon dioxide.

Carbon Dioxide Has Many Uses. In the making of bread and cakes carbon dioxide is used to cause them to "rise". Baking-powder is sometimes mixed with the flour. Baking-powder is a mixture of baking-soda and a dry acid (tartaric acid or cream of tartar). Baking-soda contains carbon dioxide just as the marble does. When the acid is wet it acts on the baking-soda and sets the carbon dioxide free. The freed carbon dioxide forms bubbles in the cake, makes it rise and so the cake is light or has "texture".

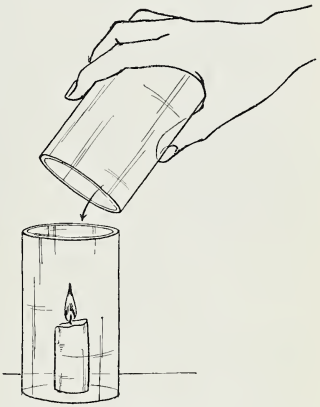


Fig. 48.
Carbon dioxide can be poured.

In bread-making carbon dioxide is produced by tiny yeast plants which are allowed to grow in the bread. Yeast has been used in bread-making for ages, but the use of baking-powder is a modern application of scientific knowledge.

The bubbles of gas in soda-water are bubbles of carbon dioxide which have been dissolved in it under pressure. Carbon dioxide gives soda-water its pleasant taste.

Does All of the Air Support Combustion? Examine the carbon left in the test-tube from the last experiment. You know that you could turn it into an invisible gas by burning it, but before it can be burned air is needed. The charcoal did not burn while it was in the test-tube because no air could reach it. Remove it from the test-tube and hold the charcoal in a flame. It burns with a steady glow. *Air is necessary for combustion;* it is said to "support" combustion.

Why does the air support combustion? Does all of the air, or only a portion of it, take part in this burning process? The following experiment will answer these questions.

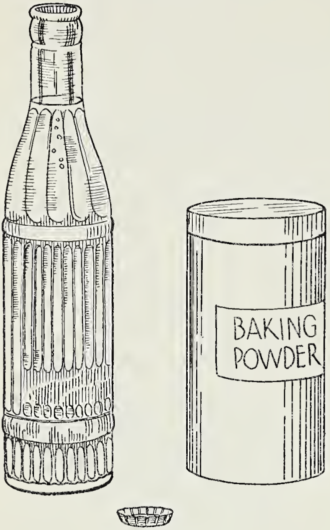


Fig. 49.
The bubbles in soda-water are carbon dioxide. Carbon dioxide which is released from baking powder causes cake to rise.

PROBLEM

Does all or only a part of the air support combustion?

Plan. In a closed vessel burn a substance which does not produce a gas. If you do so you can measure how much of the air is used up because there will be no gas in the jar to take the place of the air used. (Phosphorus will burn without producing a gas).[1]

Apparatus and Materials. A small crucible; a basin of water; a large jar and a piece of phosphorus about half as large as a green pea (Fig. 50).

Method. Place the phosphorus in the crucible and float the crucible in a basin of water. Ignite the phosphorus by touching it with a hot wire.

[1] Phosphorus is an extremely poisonous chemical. It is very dangerous to handle because it catches fire easily. The heat of the fingers is sufficient to make it burn. Phosphorus is always stored in water. If a portion of it is to be used it must be cut while it is *under* water. *A phosphorus burn is very painful.*

Quickly place the jar, mouth down, over the crucible. Thrust the mouth of the jar into the water to the depth of an inch.[1]

Observation. 1. Did all the phosphorus in the crucible burn? 2. After the white fumes had dissolved in the water, did the gas remaining in the jar resemble air? 3. How high did the water rise in the jar?

Conclusion. 1. How much of the air was used up by the burning phosphorus? 2. How much of the air supports combustion? 3. Why was there unburned phosphorus left in the crucible although there still appears to be air left in the jar? 4. Why do you think that the gas left in the jar will not support combustion?

One-fifth of the Air is Composed of Oxygen. The experiment you have just done teaches you that only one-fifth of the air is used up in burning. This leads you to conclude that only one-fifth of the air will support combustion. The other four-fifths of the air does not support combustion. There must then be at least two distinct parts to the air. One part makes up about four-fifths of the air. This part apparently has nothing to do with burning. The other and smaller portion, making up one-fifth of the air, is the part which supports combustion. This part of the air, when tested, is found to be the gas *oxygen*.

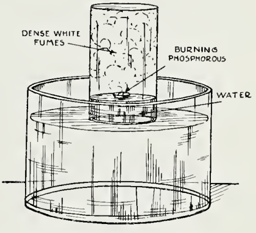


Fig. 50.

Water rises in the bottle to take the place of the oxygen which is used up when the phosphorus burns. What becomes of the white fumes?

How to Prepare Pure Oxygen. It will be interesting to prepare some oxygen in a pure state. You can do this in the following way.

PROBLEM

To prepare and test pure oxygen.

Plan. Many substances contain the gas oxygen. The oxygen can be driven out of some of them by heat. The chemical potassium chlorate is such a substance. It gives up its oxygen more readily if another chemical, manganese dioxide, is mixed with it before it is heated.

[1] The dense, white fumes from the burning phosphorus are really small particles of burnt phosphorus. These white particles will soon settle and dissolve in the water, leaving the air which remains in the jar quite clear.

Apparatus and Materials. Hard glass test-tube; one-holed stopper fitted with a glass tube; rubber delivery tube; pneumatic trough and collecting jars; clamp stand with clamp; potassium chlorate and manganese dioxide; lime-water and some splinters of wood (Fig. 51).

Method. Mix three parts of potassium chlorate with one part of manganese dioxide. Take about one third of a test-tubeful of this mixture. Insert the stopper and set up the apparatus as shown in the diagram. Heat the test-tube gently and collect the gas produced by displacement of water just as you did when you collected carbon dioxide. Collect several bottles of the gas produced. Test the gas in one bottle with lime-water.

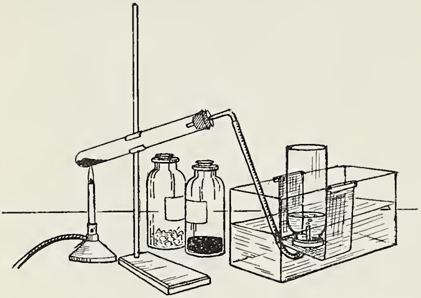


Fig. 51.—How to Prepare Oxygen
The hard glass test-tube contains a mixture of potassium chlorate and manganese dioxide.

Into another bottle thrust a glowing splinter.

Test the gas produced by the burning wood with lime-water.

Observation. 1. Does this gas turn lime-water milky? 2. Does the gas produced by heating potassium chlorate resemble air in appearance? 3. Does a glowing splinter burn more or less brightly in oxygen than in air? 4. Does the gas produced by the burning of wood in oxygen turn lime-water milky?

Conclusion. 1. Does pure oxygen support combustion as well as air or better? 2. When wood is burned in oxygen does it produce carbon dioxide as it did when burned in air? Your experiment has shown you that pure oxygen supports combustion much better than ordinary air. Only one-fifth of the air supports combustion. This is as it should be since only one-fifth of the air is oxygen.

Four-fifths of the Air Will Not Support Combustion. There still remains the four-fifths of the air which does not support combustion. Of what is this inactive four-fifths of the air composed? You will recall that when you burnt phosphorus in a jar four-fifths of the air was left in the jar unused. Repeat the experiment in order to obtain this inactive four-fifths of the air. When the fumes have all disappeared test the gas in the bottle with lime-water. The lime-water does not turn milky.

This shows you that the gas in the bottle is not carbon dioxide. Now thrust a lighted candle into the jar. The candle is immediately extinguished. The gas is not oxygen because it does not support combustion. Chemical tests show that the gas in the bottles is chiefly *nitrogen.*

Nitrogen is a very inactive gas although it makes up nearly four-fifths of the air. It does not burn or support combustion. Certain chemicals contain it and are valuable because nitrogen in mineral salts is necessary for plant growth. Nitrogen in mineral salts is very often added to the soil as a fertilizer.

The Composition of the Air. Besides containing oxygen, nitrogen and a small amount of carbon dioxide, the air also contains other gases which are named *rare gases.* The rare gases make up about one hundredth, or one per cent, of the air. One of these rare gases is *neon.* Neon is used in the making of neon signs. Another of the rare gases is *helium,* which is used in filling airships and balloons.

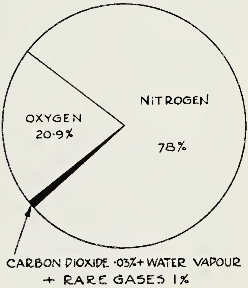


Fig. 52.
This chart shows the proportions of gases which make up the air.

You know also from your previous studies that there is also a small amount of water vapour in the air. The diagram shows the composition of the air.

Guide Words

environment	oxygen	illuminating gas
air	nitrogen	organic matter
dampers	helium	rare gases
smother	lime-water	charcoal
extinguish	gas	phosphorus
burn	marble chips	crucible
combustion	acid	potassium chlorate
carbon dioxide	gasolene	manganese dioxide
sulphur	neon	wind
fuels		

Signpost Sentences

1. .... is all around us.
2. .... is moving air.
3. A fire will .... more briskly when it is fanned.
4. .... or burning depends upon the oxygen in the air.
5. When fuels burn they use up .... from the air.
6. About one-fifth of the air is ....
7. About four-fifths of the air is ....
8. Nitrogen does not support ....
9. .... is produced whenever a fuel containing carbon is burned.
10. Carbon dioxide turns .... milky.
11. Carbon dioxide can be set free from marble or limestone by the action of .... upon it.
12. Pure oxygen can be produced by heating a mixture of .... and ....
13. .... burn better in pure .... than in air.

Questions on the Chapter

1. Why does a fire burn more brightly when it is fanned?
2. Why is the fire in a kitchen stove checked when the dampers are closed?
3. Why does pure oxygen support combustion better than ordinary air?
4. What gas is produced when a candle burns?
5. What is the test for carbon dioxide?
6. Is carbon dioxide produced when wood burns? How do you know?
7. (a) How could you prove that the following substances contain carbon: wood, sugar, starch, cloth?

   (b) How could you show that gasoline, alcohol, and candle-wax all contain carbon?

   (c) Why is a different method used in (b) than is used in (a)?
8. (a) Does carbon dioxide burn?

   (b) Does it support combustion?

   (c) Does it weigh the same as air?

Give reasons for your answers.

9. How could you prepare pure carbon dioxide?
10. Explain how baking-powder causes cake to rise.
11. From what chemicals is pure oxygen readily obtained?
12. Name the gases which compose the air. In what proportions are they to be found in the air?

Special Problems and Practical Applications

1. If you had a bottle of an unknown gas how could you tell whether this gas was oxygen, carbon dioxide, or nitrogen?
2. Why is pure oxygen used in a welding torch?
3. Priestley, an English scientist, first discovered oxygen. The French scientist Lavoisier did a great deal to prove that oxygen is the active

part of the air. Read accounts of their lives and report on them to the class.

4. An oxy-acetylene torch such as is used in welding will burn underneath the water. Explain why.

5. The pure oxygen which is sold in tanks is extracted from the air. Find out how this is done.

6. Pure oxygen is used in many ways. Can you name some of them?

7. Explain the purpose of the bellows on the blacksmith's forge.

8. Electric light globes have no air in them but are often filled with nitrogen. Why?

Home Projects

1. Make a bottle of lime-water by dissolving some lime in water.

2. Prepare some carbon dioxide gas by dissolving a half a teaspoonful of baking-powder in water.

3. Test the gas which comes from the baking-powder to see if it is carbon dioxide.

4. Can carbon dioxide be produced by the action of vinegar on limestone or egg shells?

5. Mix a little vinegar with a solution of washing soda. Test the mixture to see if the carbon dioxide is present.

6. Test some soda water with lime-water. Is carbon dioxide present?

7. Test some effervescent fruit salts with lime-water. Is carbon dioxide present? Can you explain what causes the salts to effervesce or produce a gas when they are dissolved in water?

CHAPTER VIII

FIRE

Can you answer these questions?

1. How would you start a fire without matches?
2. Have you ever started a fire with phosphorus?
3. What makes a candle flame so much brighter than a fire flame?
4. Why does coke burn without a flame?
5. What is a flame?
6. Where does a flame go when it goes out?
7. What is smoke?
8. What is a chemical fire extinguisher?

The Great Discovery. Perhaps the longest stride from savagery towards civilization was made by early man when he learned to make fire. No doubt he knew of fire long before he learned how to kindle one. Probably he first learned of fire accidentally. There are a number of ways in which he might have discovered it. Lightning sometimes kindles a fire when it strikes a tree. Early man would look upon a blazing tree at first with fear, later with curiosity. By approaching it he would discover that it gave off warmth, especially pleasing on cold days. He would soon discover that the fire could be kept burning by adding branches and twigs to it. He wished a fire for his cold, damp cave and probably took home burning brands from these natural forest fires. What a difference it must have made in his life! It drove the gloom from his dark cave (Fig. 53). It frightened away wild animals at night. By its warm, cheerful light he fashioned his stone knives and spear-heads for the hunt. On the walls of the caves lit up by the flames he painted pictures of

the men and animals he knew. Pictures of the mammoth, the wild bear and the deer which he hunted are still to be seen on the cave walls which our ancestors decorated in ages past. Among the ashes of their fires we still find the stone tools and weapons which were fashioned by the firelight so long ago.

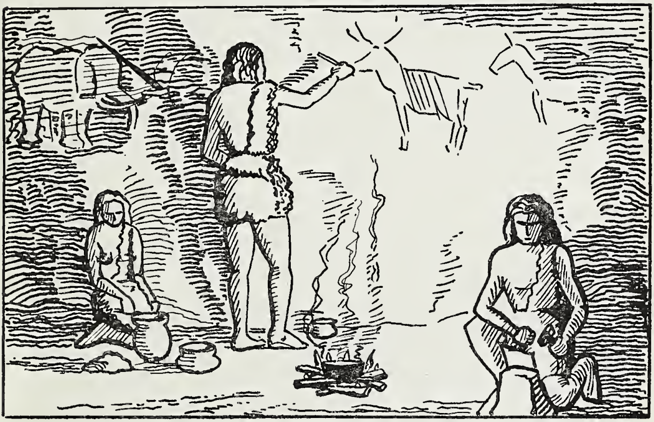


Fig. 53.
Fire changed the cave of early man into a home.

Fire changed the lair of early man into a home—cheerful, bright, and warm. It increased the number and variety of his foods. Roots and herbs when cooked became fit to eat. Meats were more tempting to the appetite.

The First Fire Wardens. The family grew up around the fire. Some one must stay home to keep the fire burning. It must never be allowed to go out. It had to be guarded carefully and plied with fuel. This was work for the children, who now became useful and appreciated.

Fire was such a boon that it was worshipped. Sacred fires were kept burning on altars in honour of the gods of fire. Everlasting fire became a symbol of life.

Man Makes Fire at Will. Accidents, however, happened then as now and, in spite of precautions, fires did go out. When man had learned to use fire and to depend upon it he felt its loss keenly. It was difficult to replace. Many days might go by before he could again secure fire. Then someone discovered how to *kindle* a fire. This was a great achievement. To the

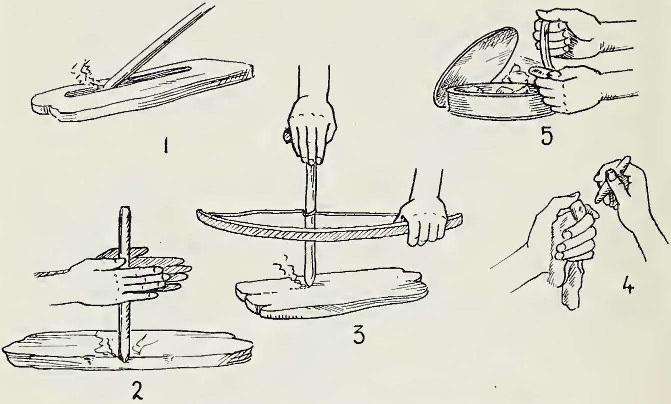


Fig. 54.—Steps in the Progress of Making Fire

(1) Rubbing two sticks together. The friction causes sufficient heat to kindle the sticks. (2) the hand-drill. (3) the bow-drill. (4) flint and steel. A spark, which ignites the tinder held in the hand, is struck from a piece of steel. (5) the tinder box. A piece of spring steel is held in the hand. Which of these methods do you think would be the most satisfactory?

modern boy or girl the making of a fire is simple: a match is struck, a piece of paper is lighted and a few dry sticks are kindled; or the gas in the gas-range is lighted. Science has made it possible for us to do these things. But how did the cave-man kindle his fire. He had no matches. To understand how he did it we must learn more about fire.

We have already learned that in the burning of such fuels as wood the carbon of the fuel combines with the oxygen of the air. But carbon does not combine with oxygen merely by being placed

in it. It must be started or kindled. If a small dry stick is dropped on a red hot stove it will smoulder at first and will then burst into flame. Clearly the heat started the burning. How could early man obtain heat to start his fire? He had no doubt observed that when two sticks were rubbed together they became warm. The *friction* or rubbing had heated them. The harder and more vigorously they were rubbed the warmer they became. With patience and much rubbing of dry sticks some early man kindled a fire. Once the sticks were made to burn the heat from the burning was used to kindle other fuel. As time went on the method of rubbing sticks improved. Labour-saving devices were discovered. Study the diagrams in Figure 54; they illustrate some of the methods used by primitive people to kindle fires.

In later times men started fires more easily by using flint and steel. When these are struck together a spark is given off. The spark is caught in tinder.[1] The tinder ignites and the burning tinder is used to start a fire. The tinder, the flint and the steel used to be kept in a small box called a tinder-box. You may have watched a mechanic sharpening tools on an emery-wheel. When the steel touches the spinning emery a great number of sparks fly off. Could they be used to start a fire? In your history you have read of flint-lock guns that were used at the time that people used tinder-boxes. Can you explain how these flint locks worked?

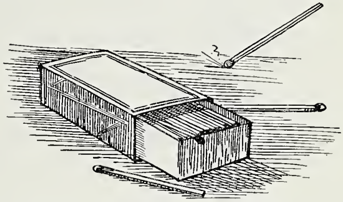


Fig. 55.—The Modern Way of Starting a Fire

Science Develops Matches. Matches such as we use are the result of a scientific knowledge of fuels and the nature of burning. Before anything will start to burn it must be heated. Some substances require more heat than others. Gasoline will start to burn or kindle more easily than coal oil; coal oil more

[1] *Tinder:* Scorched linen, dried moss, rotted wood were used to catch the sparks from the flint and steel. The spark caused the tinder to glow.

easily than wax; wax more easily than wood; wood more easily than coal. Different materials have different *kindling temperatures.* The substances above are listed in the order of their kindling temperatures. How can the order of kindling temperatures be determined. What is the order of the kindling temperatures of the following: wood, celluloid, phosphorus, sulphur?

PROBLEM

To determine the relative kindling temperatures of a number of substances.

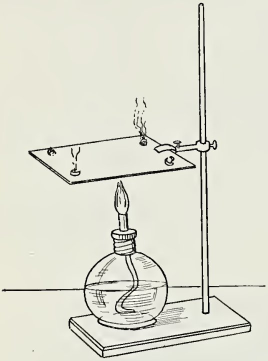


Fig. 56.
The substance with the lowest kindling temperature will ignite first.

Plan. If we gradually heat the substances all at the same time the substance with the lowest kindling temperature will begin to burn first. This can be done by placing them on a piece of sheet iron and slowly heating the iron.

Apparatus and Materials. A piece of sheet iron, some celluloid, phosphorus, wood shavings, sulphur, a spirit lamp or a bunsen burner (Fig. 56).

Method. Place a small quantity of sulphur on one corner of the sheet iron, a small piece of phosphorus on another corner, a piece of celluloid on a third and some wood shavings on the fourth. Place a spirit lamp under the centre of the iron and allow the iron to heat slowly.

Observation. As the iron heats note the order in which the materials kindle.

Conclusion. Which material has the lowest kindling temperature? Which has the highest? Which material would kindle most easily in starting a fire?

The Fire Ladder. Phosphorus ignites so readily that, for safety it is always stored in water. When it is necessary to cut phosphorus, the cutting is done under water. The friction of the knife blade is sufficient to raise phosphorus to its kindling point. If it were cut in the air it would probably burst into flame. This fact is made use of in the manufacture of matches. The "strike-

anywhere" matches (Fig. 57) we use today are tipped with a compound of phosphorus and sulphur. When the tip is rubbed on a rough surface the friction makes enough heat to kindle the phosphorus. The burning phosphorus kindles the sulphur. The heat from the burning sulphur kindles a mixture of glucose (a kind of sugar) and lead oxide. This in turn, kindles the paraffin wax in which the match-stick has been dipped. The heat of the burning wax kindles the wood. All this happens when a match is struck. Once the match is struck fire develops step by step.

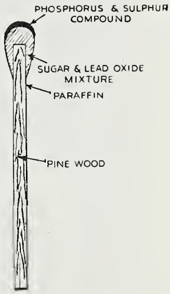


Fig. 57.—The Parts of a Match

To light a fire readily you must lay it properly. Experience has taught that some materials with low kindling temperatures (such as paper, dry shavings, dry moss or twigs) should be placed at the bottom. Above this, kindling, or small dry sticks, should be placed and then larger sticks or coal. We observe that fuels having low kindling temperatures are used to ignite those having higher kindling temperatures just as was done when the match was struck.

Flame. Some fuels when ignited flare up explosively with much flame. Others merely glow with little or no flame. Fuels which kindle most readily have most flame. You can learn why this is so by studying a candle flame.

Problem

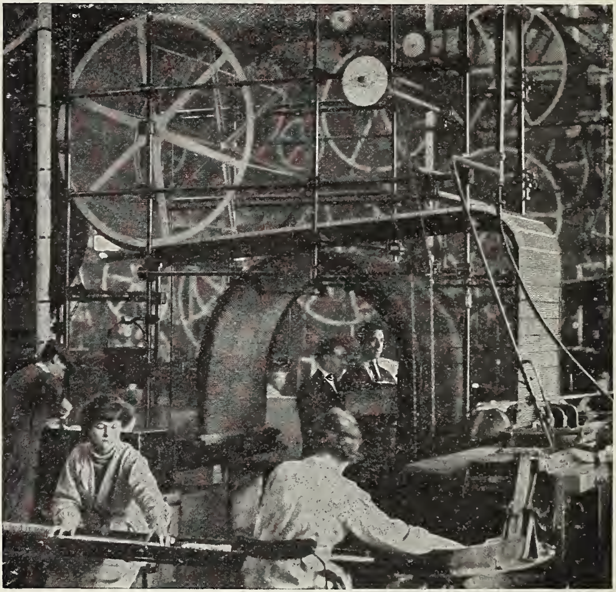
To discover the nature of a flame.

Plan. A burning candle will give a very satisfactory flame because it will be steady.

Apparatus and Materials. A candle, a piece of blotting paper, a small sheet of glass, two black-board erasers, a bunsen burner or a spirit lamp.

Method. 1. Light the candle. Observe the flame. 2. Place a piece of clean blotting paper across the middle of the flame and keep it there until it begins to char. Do not let it flame. 3. Place one corner of the sheet

of glass across the centre of the flame and hold it for a few seconds. Turn to another corner of the glass plate and hold it at the tip of the dark inner cone. Hold a third corner just at the tip of the bright cone. 4. Light the spirit lamp (or bunsen burner) and strike the black-board brushes together above it so that the chalk dust will enter the flame. 5. Hold a cold object above the spirit lamp flame for a few seconds.



Courtesy Bryant and May, London

Fig. 58.—Making Matches

The match is a contribution of science to modern civilization.

Observation. 1. How many different parts can you distinguish in the candle flame (Fig. 59)? (a) Where is the flame brightest? (b) Where dullest? Is there a bluish coloured part? If so where do you find it? Does there appear to be any substance in the dark cone surrounding the wick? 2. What is the general shape of the charred mark on the blotter? 3. Was there an equal amount of carbon (soot) deposited on each corner of the glass? Which part of the flame gave the greatest deposit of carbon? Which the least? 4. What change took place in the spirit lamp flame when the chalk dust entered it? 5. Was there any carbon deposit from

the spirit lamp flame? 6. Was there any water vapour condensed from either flame?

Conclusion. Is the burning taking place uniformly throughout the flame? What would lead you to believe that part of the flame is not burning and that most of the burning is taking place on the outside of the flame? Which part of the flame contains the greatest amount of unburned carbon particles? Which part the least? Is there any relation between the number of unburned carbon particles and the brightness of the flame? Why does the chalk dust make the spirit lamp flame more bright? From where does the water vapour come?

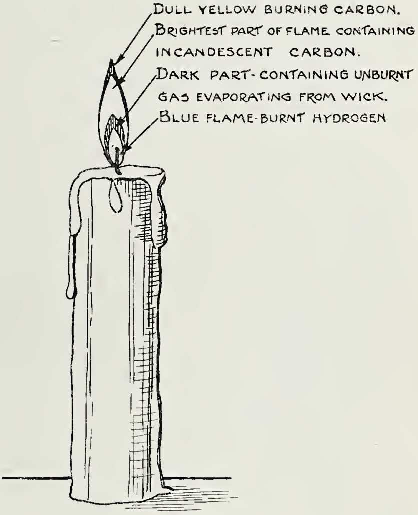


Fig. 59.
Study a candle flame to see if you can identify the parts shown above.

In your observation of the candle flame you noticed that the flame is not uniform. There is a dark central cone about the wick. Outside this is the brightest part of the flame. The very outside of the flame is not as bright as the second cone. This is more noticeable at the tip of the flame. The observation of the blotting paper tells you, however, that the brightest part is not the hottest part. The hottest part is around the outside edge. The greatest amount of burning takes place on the outside edge of the flame where it comes in contact with the oxygen of the air. The dark, central cone is made up of unburned gases which are evaporating from the melted paraffin in the wick. These gases do not give off light or heat because they are not burning.

The brightest part of the flame is the part which gave the greatest deposit of carbon (soot) on the glass. The brightness of the flame depends upon the number of unburned carbon particles in it. Flames are burning gases. Many flames are nearly colourless. The candle flame is bright because the burning gases heat the carbon particles to white heat. The white hot or incandescent particles give off light. The flame of the spirit lamp is not bright because the burning gases in the flame contain very few unburned carbon particles. The flame of the spirit lamp was brightened by putting chalk dust particles into it. The chalk dust particles became *incandescent* (or glowing) but they did not burn. In the candle flame, the carbon particles, however, burn up, with the result that the outside and tip of the candle flame do not give off bright light.

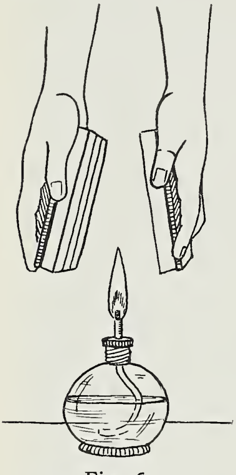


Fig. 60.
Why does the spirit-lamp flame become bright when the chalk dust enters it?

Compare a bunsen flame with a candle flame. The candle flame is brighter but the bunsen flame is hotter. The air supply of the bunsen flame allows the carbon particles to burn before they become incandescent. If you shut off the air supply by covering the vent-holes (or air-holes) at the bottom of the mixing tube (Fig. 61) the bunsen flame will become bright. This happens because there is not enough air reaching the burning gases to burn the carbon particles completely. The carbon particles, soot, will be deposited on any object held in the flame.

Hydrogen. Besides carbon *hydrogen* is found in many fuels. Hydrogen is a highly *inflammable gas*. When mixed with air it burns explosively. Examine the candle flame again. The bluish

colour you notice at the base of the flame is due to burning hydrogen. When hydrogen burns it unites with the oxygen of the air just as carbon does but the new substance formed is not carbon dioxide. It is *water vapour.* By holding a cold object above the flame the water vapour formed by the burning hydrogen will condense on the cold surface.

The hydrogen found in fuels is usually combined with carbon. Hydrogen is not found in a pure state in nature but it can be prepared in the laboratory.

This experiment should be performed only under the direct supervision of a teacher well-trained in science.

PROBLEM

To prepare hydrogen and to study it.

Plan. Hydrogen is found combined with other substances and will have to be extracted from one of them. It can be forced from certain acids by replacing it with a metal such as zinc.

Apparatus and Materials. An erlenmeyer flask, a two-hole stopper, a thistle tube, a delivery tube, a pneumatic bath, a candle, wood splints, collecting bottles, zinc metal, hydrochloric acid (Fig. 62).

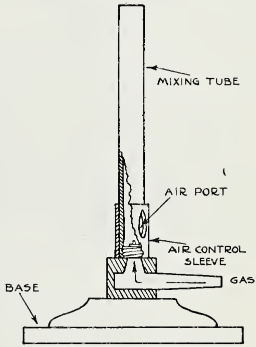


Fig. 61.—A Bunsen Burner
Explain the use of each part.

Method. Arrange the apparatus as you did for making carbon dioxide and as is shown in the diagram. Place some zinc metal in the erlenmeyer flask. Insert the two-hole stopper. (CAUTION: be sure there is no flame near the apparatus.) Pour diluted hydrochloric acid down the thistle-tube. Allow the first gas which is formed to escape in order to drive out the air. Collect several bottles of the gas as you did when you collected carbon dioxide and oxygen. The bottles of hydrogen should be kept upside down to prevent the gas from escaping. 1. Put a lighted splint to the mouth of one of the bottles. 2. (a) Insert a lighted candle into an inverted bottle of gas. (b) Withdraw the candle slowly. 3. Allow a bottle of hydrogen to mix with a bottle of air by placing the bottle of hydrogen over the bottle of air. Let the bottles stand for a few minutes; then test each quickly with a lighted splint. 4. Note carefully what happens in each case.

Observations. 1. Are bubbles of gas formed when hydrochloric acid is poured on zinc metal? 2. Will hydrogen burn? 3. What is the colour of a hydrogen flame? 4. Is it a bright flame? 5. Did the candle continue

to burn when it was thrust into the bottle of hydrogen? 6. Was the hydrogen burning at the mouth of the bottle? 7. What effect did mixing hydrogen and air have on the rate of burning?

Conclusion. 1. Does the gas produced by the action of hydrochloric acid on zinc metal resemble air? 2. Does hydrogen burn? 3. Does hydrogen support combustion?

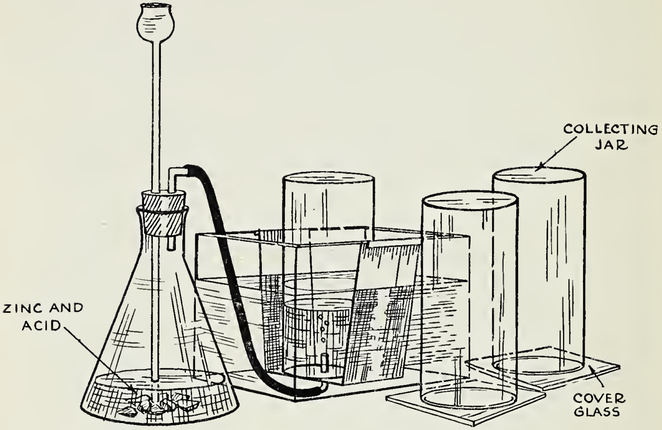


Fig. 62.—Preparing Hydrogen
Why are the bottles of hydrogen kept upside down?

Hydrogen is so inflammable that great care must be taken to keep the flames away from the apparatus while it is being prepared. Hydrogen burns explosively when it is mixed with air. Water vapour is then formed. When cooled the water vapour condenses.

Nearly all fuels which burn rapidly contain much hydrogen. Coal gas and natural gas contain so much hydrogen that they form explosive mixtures with air. Coal oil and gasolene are very inflammable liquids which contain hydrogen. They evaporate easily and their vapours form explosive mixtures with air. For this reason it is extremely dangerous to kindle a fire in a stove with coal oil or gasolene. A pound of gasolene if mixed with the

proper amount of air can do more damage than a pound of dynamite.

The flames coming from a wood fire are the result of burning gases driven out of the wood by the heat of the fire. Some woods such as cedar and pine produce much flame because they contain inflammable oils which evaporate very easily. After the inflammable hydrogen compounds are all driven out of the burning wood only carbon remains. When pure carbon is burning it does not produce a flame. This is why the embers glow but have no flame.

Coal Gas. One of the most convenient fuels to use in the home is coal gas. As the name suggests it is prepared from coal. A piece of hard, black coal does not look as though much gas could be taken from it. However, if you do the next experiment you will have an idea of the amount of gas there is in coal.

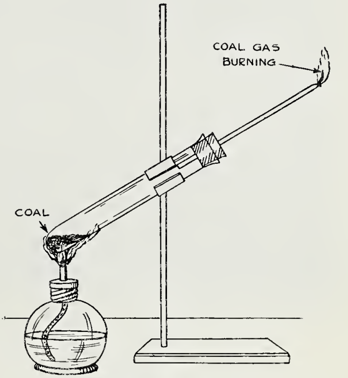


Fig. 63.—Distillation of Coal

A model gas works. When the coal is heated in the test-tube coal gas is produced.

PROBLEM

To extract gas from coal.

Plan. You know that heat drives the inflammable gases out of burning fuels. You can make use of this fact in the experiment.

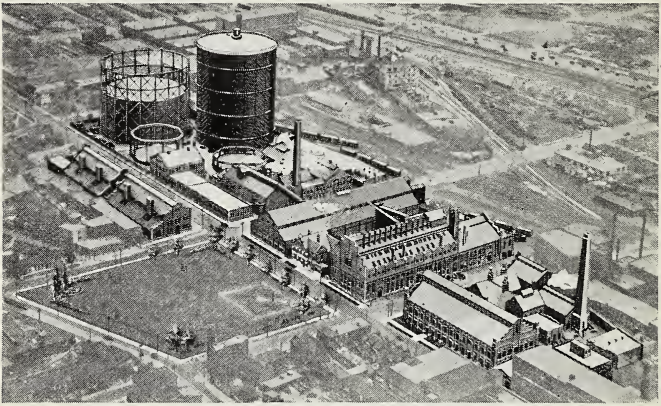
Apparatus and Materials. A hard glass test-tube, a one-hole stopper, a glass tube to fit; some coal.

Method. Put a small amount of powdered coal in the test-tube as shown in Figure 63. Heat the test-tube gently at first and gradually increase the heat. Touch a lighted match to the end of the glass tube.

Observations. 1. Does the gas which comes from the glass tube burn? 2. Is there any deposit along the sides of the glass tube? 3. Collect some of the deposit and smell it.

Conclusion. 1. Can coal gas be driven out of coal by heating the coal? 2. How is coal tar produced? 3. What material is left in the test tube after all the gas is driven out?

The process of breaking up materials by heating them in a closed vessel is called *destructive distillation* because the original materials are destroyed and new ones are formed. When you extracted the coal gas from the coal you saw that coal tar is produced as a by-product of this destructive distillation. The carbon which remains becomes a hard, porous mass called *coke.*



Courtesy the Consumers' Gas Company of Toronto

Fig. 64.—A Modern Gas Works

Coal gas is prepared in large quantities by heating bituminous, or soft, coal in large airtight retorts or pots. The gas which is driven out is passed through long, cooled tubes where the coal tar condenses and is removed. The coal gas is washed or passed through water and stored in large tanks called *gasometers.* From the wash-water ammonia and other valuable chemicals are recovered.

From the gasometers the gas is conducted through mains under the street to dwelling houses and factories. The coke taken from the retorts is sold as furnace fuel. The coal tar is used for surfacing roads and tarring roofs. From coal tar valuable chemicals

can be extracted, such as coal-tar dyes. From these coal-tar chemicals many perfumes, flavouring extracts and medicines are made.

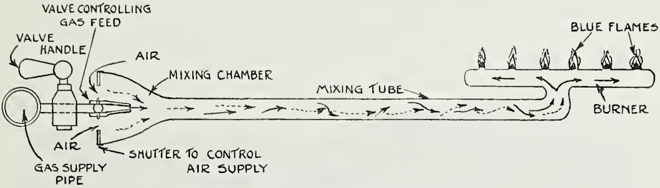


Fig. 65.—A Gas-Stove Burner
Air and gas are mixed in the tube. This mixing causes better combustion at the openings in the gas plate.

The Bunsen Burner. Special devices or methods are used to burn coal gas. You will recall that burning requires oxygen. These devices provide a constant supply of air for the burning gas flame. Examine a bunsen burner. Notice how the gas is mixed with air before it is burned. Notice how the amount of air entering the burner is regulated. What prevents the mixture from exploding in the mixing tube?

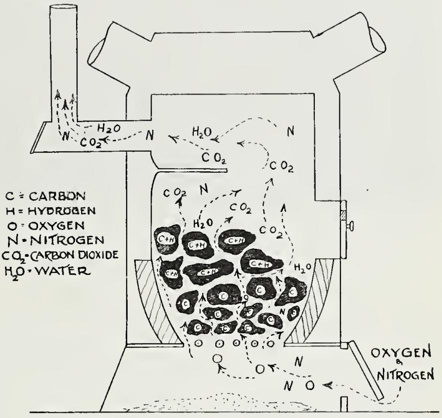


Fig. 66.—A Hot-Air Furnace
Air is necessary to keep a fire burning. Study the diagram and explain the processes of combustion in the furnace.

Compare a bunsen burner with a gas-stove burner. If you have a gas stove at home, examine the burners on it. If soot is being deposited upon the kitchen pots and pans, the burner is not getting enough air.

Fuels. The chief sources of fuels are forests, coal mines, gas wells and oil wells. Some countries are well supplied with forests. These supply wood fuel. In countries where wood is scarce, coal

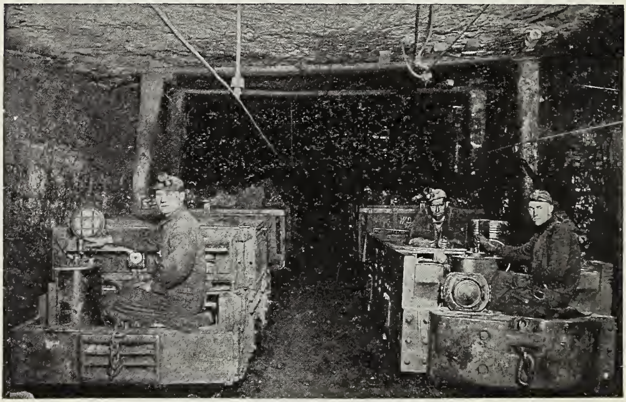


Fig. 67.—Interior of a Coal Mine
Coal is valuable as a fuel because it contains much carbon.

is often used as fuel. The coal in the ground was formed from the great forests of by-gone ages. The shafts and tunnels which are dug in the ground to recover the coal are called coal mines. There are different kinds of coal. Some coal is very hard and contains very little gas. Such coal is called *anthracite* coal. Other coal is soft and full of gas. This is *bituminous* coal. Secure specimens of each kind and learn to distinguish between them.

Petroleum, or oil, also comes from the ground. It was formed at the same time as the coal by pressure and heat. While it was

forming a great deal of gas was produced. The gas collected underground in pockets. This natural gas, like coal gas, can be used for fuel.

Petroleum is an excellent fuel. A pound of petroleum when burned will give more heat than a pound of any other common fuel. It is valuable also because it contains many other substances which have become necessary in our modern civilization. Gasolene, coal oil, lubricating oil, petroleum jelly, paraffin wax, and asphalt are all extracted from petroleum.

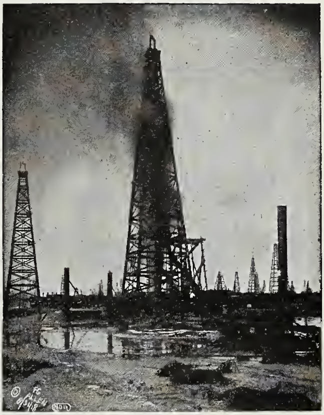


Fig. 68.—Oil Wells
Oil is a fuel rich in carbon and hydrogen.

Fire Control. Although fire is a very useful servant it needs careful and constant watching. Once out of control it is destructive and dangerous. A carelessly tossed match or cigarette or an unextinguished camp fire may cause the loss of valuable forests. Thousands of dollars are spent annually to guard against forest fires and to fight them. Every city has to maintain a fire department to protect the homes of its citizens. Fire is a constant menace.

Study Figure 69 to see if you can locate all the possible causes of fire which it illustrates. Examine your home. Is there any danger of fire there? Your home probably cost several thousand dollars to build. Fire could destroy it in a few minutes. It is the duty of every one to watch for fire hazards and to guard against them.

If you live in a city, make yourself familiar with the methods used there for fighting fires. In your record book write down

what you would do if you discovered that your home was on fire. Write down the location of the nearest fire alarm box, and the telephone number of the fire department.

Towns and cities are put to great expense to install fire-fighting equipment. Besides the extra water-mains and hydrants fire-trucks are needed to carry equipment and firemen whenever a fire occurs. The trucks must carry chemical fire-extinguishers for

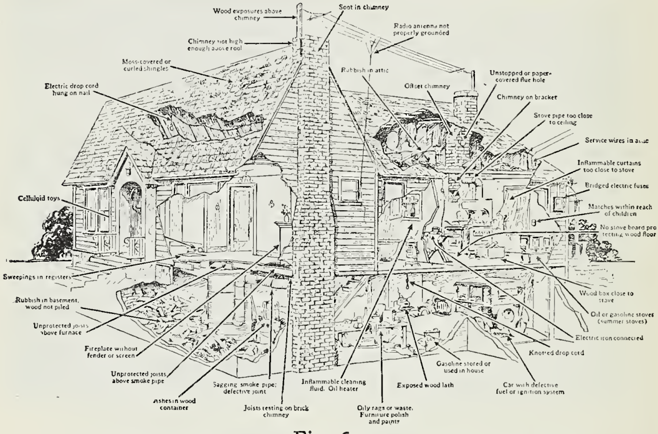


Fig. 69.

Are there any of these fire hazards around your home?

use in case water is not available or is not the most suitable substance for extinguishing the fire. Water, for example, is not suitable for extinguishing a fire of burning oil, as oil floats upon water and the water may help to spread the fire. For putting out such a fire, chemicals are used. These make a froth which spreads over the oil and keeps the air away.

Fire-Extinguishers. Many public buildings have chemical fire-extinguishers placed where they can be easily reached. These are used in case of emergency. A common type of extinguisher is the one pictured in Fig. 70. It contains a solution of bicarbonate

of soda (baking-soda) in water. The bottle at the top contains acid. It has a loose stopper made of lead. When the extinguisher is turned upside down the stopper falls out of the bottle and the acid mixes with the solution. Carbon dioxide is then produced. This gas rises in the tank and sets up a pressure which forces the liquid out of the nozzle.

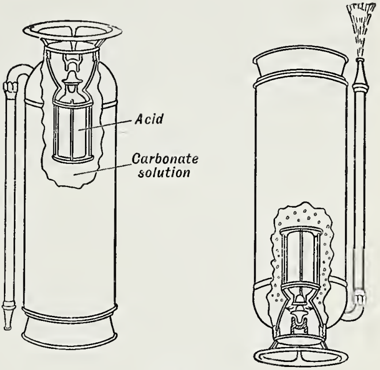


Fig. 70.
These diagrams illustrate a commercial fire extinguisher. Compare it with the model in Fig. 71.

You can easily make a model of this type of extinguisher. Secure an erlenmeyer flask, a small vial, a short glass rod and a rubber stopper fitted with a rubber hose and nozzle as shown in the diagram. Fill the erlenmeyer flask half-full with a solution of baking-soda (about a teaspoon to a pint of water). Fill the vial with acid (be very careful not to get acid on your skin or clothes). Fasten the vial to the glass rod and lower it carefully into the erlenmeyer flask. Insert the stopper firmly. When the fire-extinguisher is turned upside down the gas will force the liquid out of the nozzle.

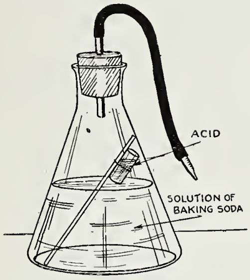


Fig. 71
When the model fire-extinguisher is inverted the liquid squirts from the nozzle with force.

Guide Words

kindling temperature	fire	lightning
destructive distillation	fuels	flame
flint and steel	friction	tinder
coke	match	phosphorus
sulphur	explosive	incandescent
inflammable	gasolene	carbon
soot	hydrogen	zinc
acid	petroleum	fire-extinguisher
		oxygen

Signpost Sentences

1. The discovery of a method to kindle .... was one of the first steps toward civilization.
2. .... will generate sufficient heat to start a fire.
3. Fuels will not ignite until raised to their ....
4. When a match is struck the friction raises the .... compound of the tip to its kindling temperature.
5. The brightness of a candle flame depends upon the amount of .... carbon particles in it.
6. When .... burns it produces water vapour.
7. Coal gas is manufactured by the .... of coal
8. Water is a good .... because it cools the burning material below its kindling temperature and also because the steam formed smothers the fire by keeping the .... away.
9. Carbon and hydrogen are found in all common ....

Problems on Chapter VIII

1. In what way did the discovery of fire affect man's food supply?
2. Describe three ways of making fire before the invention of matches.
3. Why is a ''strike-anywhere'' match tipped with a phosphorus compound.
4. Draw a diagram of a candle flame and explain each part.
5. A bunsen flame will give bright light if chalk dust is sprinkled into it. Why?
6. Explain why burning wood produces a flame.
7. Why is water a good fire-extinguisher?
8. Why is water not used to extinguish oil fires?
9. What gas is formed when acid is poured on baking-soda?
10. Why will the baking soda and acid type of fire-extinguisher put out a flame? Give two reasons.

Special Problems and Practical Applications

1. Name three substances you would expect to find in the smoke from your chimney.
2. How could you prove that a burning flame contained hydrogen.

3. On an outline map of Canada mark:
   (a) The forested areas of Canada.
   (b) The coal-mining areas.
   (c) The natural-gas areas.
   (d) The oil-producing areas.
(Your text book on Geography will furnish you with the information).

4. Read about the coal beds and report to the class what you find out about them.

5. Show how a match is a practical application of a knowledge of kindling temperatures. Describe a match and explain the use of each part.

6. Tell how you would lay a camp fire. Give a scientific reason for each step you take.

7. Explain how a bunsen burner operates.

8. Make a study of safety matches and report to class.

Home Projects

1. Make a bow-drill and try your luck at kindling a fire with it.

2. See if you can set wood on fire by means of a magnifying glass and sunlight.

3. Make a fire-extinguisher from a bottle. Use baking-soda and vinegar for your chemicals.

4. Make coal gas for yourself. Heat some powdered coal in a jam tin. Put the cover on tightly and punch a small hole in it. Be sure all the air has been driven out of the tin before you attempt to light the gas coming from the hole.

5. Examine your home for fire hazards and try to have them removed.

CHAPTER IX

AIR AND LIVING PROCESSES

Can you answer these questions?

1. Is it possible to drown a fish?
2. Can you "smother" a plant?
3. Does a fish breathe?
4. What becomes of air after it enters your lungs?
5. Why do you breathe?
6. What is the purpose of the blood?
7. Why does your heart beat faster when you run?

What Do You Breathe? You breathe so unconsciously that you rarely observe that you are breathing. Now and then, however, your breathing is brought to your attention. You have noticed that you breathe much faster when you run. After a hard run you do not seem to be able to breathe enough. There was something you were striving to obtain. What was it?

Place your fingers over your mouth and breathe in. What do you feel going through your fingers? Air! Now breathe out. What do you feel again? Air! It is plain that air has something to do with your breathing. In fact to obtain air is the purpose of your breathing. You have need of the air. In play, sometimes, you may have been partly smothered. How pleasant a breath of air seemed then! You know that in swimming you must come to the surface of the water to breathe. If you do not, you will drown for want of air.

The Breath of Life. If you were provided with water and air you could live several weeks without food. If, however, you had air only you could live several days without water. But you would die in a very few minutes if your supply of air were shut off. Try holding your breath for just one minute. A minute

seems a very long time. Why do you become distressed after holding your breath for only a few moments? What is in the air that is so necessary to life?

Air, as you know, is composed mainly of two gases, nitrogen and oxygen (Fig. 52). About four-fifths of the air is nitrogen and about one-fifth of it is oxygen. If small animals such as mice be placed in pure nitrogen they quickly suffocate. If they are placed in pure oxygen they live. People who have been nearly suffocated by drowning, or by breathing smoke or fumes often are revived by being allowed to breathe pure oxygen. This would lead you to suspect that you breathe in air to secure oxygen from it.

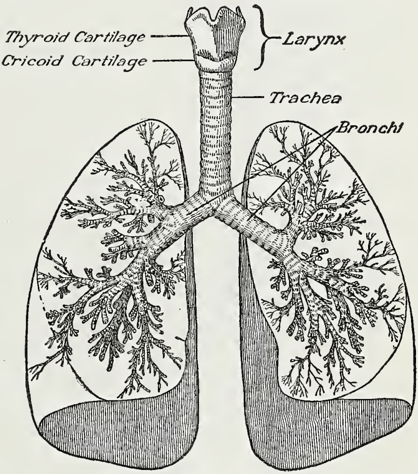


Fig. 72.—The Lungs
This diagram shows the trachea and bronchial tubes through which air passes on its way to the air-sacs of the lungs.

Why do you need oxygen? Where does it go when you breathe in the air? To answer these questions you must know something about the human body. When you inhale or breathe in air, it goes through your nostrils into your lungs. In its journey the air passes through the trachea, or wind-pipe, and its branches, the bronchial tubes. In the lungs the bronchial tubes end in little sacs or pockets (Fig. 72). These sacs are surrounded by tiny tubes which contain blood. These tubes are called blood-vessels. The lungs are a spongy mass of small air-pockets and tiny blood-vessels.

When you exhale or breathe out, the air in the small air-sacs in your lungs is forced back through the bronchial tubes. From the bronchial tubes it is forced into the trachea and from there it goes through the nose or mouth to the outer air again.

Something must have happened to the air while it was in the lungs. What did happen to it? If you test the air which you have exhaled and find that it is different from ordinary air it may help you in solving the problem.

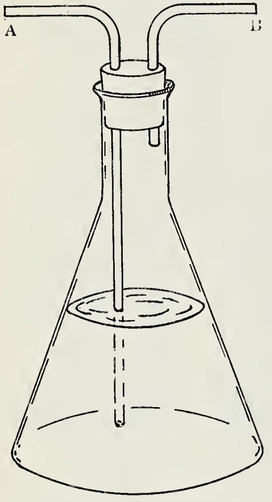


Fig. 73.—An Experiment to Demonstrate that Inhaled Air Differs from Exhaled Air

PROBLEM

Is the air which you exhale different from the air which you inhale?

Plan. You already know that the part of the air you require for keeping you alive is oxygen. Is it possible that the oxygen becomes used up when you inhale air? If so, carbon dioxide might be produced. You might suspect this because carbon dioxide was produced when a burning candle or piece of wood used up oxygen. You might test the air before you inhale it and after you have exhaled it in order that you may find out if it contains more carbon dioxide after it has been in your lungs than it had before.

Apparatus and Materials. An erlenmeyer flask, a two-holed stopper, bent glass tubes, lime-water.

Method. Pour a little lime-water into the erlenmeyer flask. Insert the stopper, as shown in the diagram (Fig. 73), so that only one of the two bent glass tubes reaches below the lime-water. 1. Inhale air by placing tube *B* in your mouth and drawing air through the lime-water. 2. Test the exhaled air by placing tube *A* in your mouth and blowing air from your lungs through the lime-water.

Observation. 1. Was there any noticeable change in the lime-water when the air was drawn through it into your lungs? 2. What change was there in the appearance of the lime-water when the exhaled air was blown through it?

Conclusion. 1. Is carbon dioxide found in exhaled air? 2. Was it produced in your body?

Your experiment has just shown you that carbon dioxide was exhaled from your lungs. It must have been produced in your body. Before it was produced, however, oxygen was used up. The oxygen was taken from the air. What processes in your body used the oxygen and produced the carbon dioxide? How was the change brought about? Why was the change necessary? Before you can attempt to answer these questions you must know more about the human body.

The Body is Composed of Living Cells. The biologist can help you here. A biologist is a scientist who studies living things. With the aid of the microscope, by which cells may be magnified or made to appear larger than they really are, biologists have discovered that such parts or tissues of animals as muscle and flesh are made of millions of very tiny box-like *cells*. These cells are fitted closely together just as are the bricks of a house. A single cell in the body is so small that it cannot be seen unless it is very highly magnified. The cells, however, are not all alike in appearance. They differ in size and in shape. Those cells which are found in your blood are quite different in appearance from the cells which make up bone or the tissues of your skin. Nerve and brain cells are different in size and appearance from those which compose your muscles (Fig. 76).

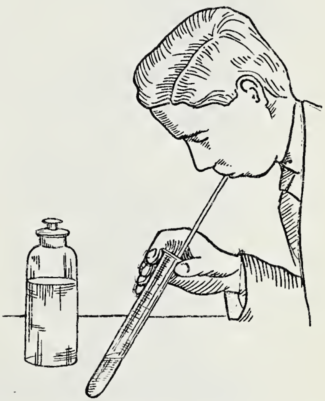


Fig. 74.
The air which is exhaled from the lungs contains carbon dioxide. This can be proved by blowing through limewater. Carbon dioxide turns limewater milky.

All living cells are alike in this respect, however, that they all

contain a jelly-like substance called *protoplasm.* This jelly-like protoplasm is the actual living part of the cell and, since the body is made of cells, the living part of the body is protoplasm. It is this protoplasm which requires the oxygen of the air. When living protoplasm is prevented from obtaining oxygen it dies. This is why the air, or rather the oxygen in the air, is so necessary in maintaining life.

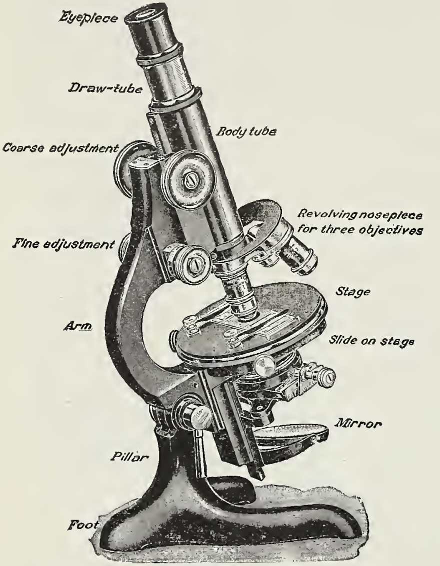


Fig. 75.—A Microscope

By the use of the microscope much has been learned about cells.

All living or organic material, including protoplasm, contains carbon as one of the elements composing it. Living protoplasm causes the oxygen to unite with or join some of this carbon and so carbon dioxide is produced. This process of the uniting of oxygen with the carbon of the protoplasm is called *respiration.*

Energy is Necessary for Life. The purpose of respiration is to release or set free *energy.* Energy is that which enables things to do work or to move. Automobiles move because of the energy which is set free when a mixture of gasolene and air is exploded in the cylinders of the engine. The explosion is caused by the sudden burning of the carbon and other fuels in the gasolene.

Similarly a railroad engine moves because of the energy released when the coal burns in the fire box.

You are able to walk, to run, to think and to live because you

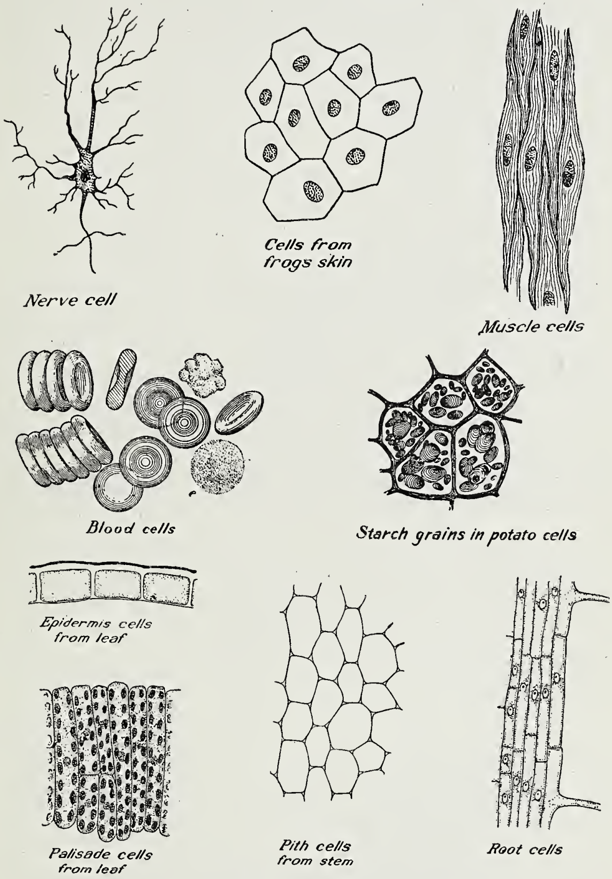


Fig. 76.—Types of Cells, Highly Magnified

use energy. The energy you use is released by the process of respiration going on in every living cell in your body.

Energy is produced in many forms. When fuels burn, energy is released as heat and light. When a mixture of air and gasolene explodes, energy is released in the form of movement. When respiration takes place within the cells there are released the energy of heat, and nervous energy, and also the muscular energy which enables you to move. Energy in the form of light is very seldom released in animal cells. In the cells of the glow-worm, however, and of the fire-bug and of certain tiny sea animals we have exceptions to this rule. Here we find that energy is sometimes released by animal cells in the form of light.

Carbon is not the only substance used by protoplasm as a fuel for the release of energy. Organic material always contains hydrogen as well as carbon. Water vapour is produced when hydrogen unites with oxygen. By breathing on a piece of cold glass you can demonstrate that water vapour is produced in respiration.

Only through your lungs can oxygen enter your body. How then does it reach each one of the many millions of cells in your body? Here is a suggestion as to the answer to this question.

The Circulation of the Blood. You have observed that you breathe faster when you are running than you ordinarily do. Did you notice that your heart was beating faster also? You already know why running causes you to breathe more rapidly: you need more oxygen to supply the muscle-cells. The oxygen makes it possible for the fuels in these cells to be used up. Respiration in the cells becomes more rapid and so much muscular energy is released.

Your heart has a great deal to do with the taking of oxygen to these cells (Fig. 77). The heart is the centre of the system which circulates the blood through your body. Just as a diver under the water must have air pumped to him through a rubber hose, so the cells of the body must have oxygen pumped to them.

The oxygen which you inhale is carried to the body-cells by the blood. When air enters your lungs it comes into close con-

tact with the tiny blood-vessels which surround the air-sacs. The blood contains red *corpuscles* or cells which absorb, or take in, the oxygen from the air in the lungs. The blood with its supply of oxygen then flows through larger blood-vessels to the heart. From the heart the blood is pumped to all parts of the body through large tubes or blood-vessels called the *arteries*. From the large arteries the blood travels through smaller blood-vessels, the *capillaries*. These tiny capillaries enable the blood to reach all of the body cells. The oxygen of the red blood-corpuscles is then given up to the cells. After giving up their oxygen the red blood-corpuscles receive the carbon dioxide which is produced by the respiration of the cells. The blood then makes its way from the capillaries into the *veins*. These veins conduct it back to the heart. The heart now pumps the blood to the lungs. In the lungs red blood-corpuscles give up their carbon dioxide and take in a new supply of oxygen. The whole process is repeated again and again so long as the heart keeps pumping. The body is able to store up enough oxygen to keep

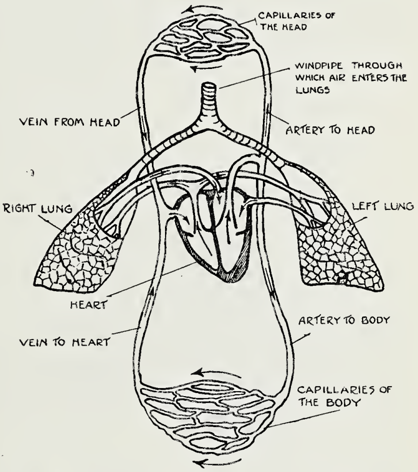


Fig. 77.—The Circulation of the Blood

The blood is pumped to the lungs by the heart. After passing through the capillaries of the lungs it returns to the heart. It is then pumped to all parts of the body from where, after passing through the capillaries, it returns to the heart again. By following the arrows you can trace the path of the blood.

it respiring for only a very short time. It is therefore necessary for us to breathe at all times and for the blood to be kept circulating whether we are waking or sleeping, working or playing.

Now you will be able to understand why your heart beats faster when you are running or playing: your muscle cells then need more oxygen. The heart, therefore, must send more blood to them.

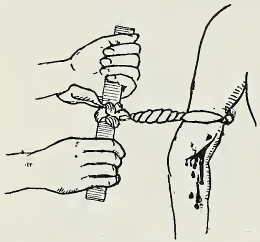


Fig. 78.—Using a Tourniquet
Which has been cut—a vein or an artery?

Fresh Air and Health. Some vigorous daily exercise is good for the health. The heart beats faster and more strongly because of it; all the cells in the body receive blood and oxygen and so are enabled to grow and live properly. But when you do your daily exercises do them in the open or in a properly ventilated room. Otherwise most of the value of your exercises will be lost. You need fresh air as well as exercise.

Tobacco and alcohol have serious effects upon the nerves which control the heart muscle. The use of tobacco hinders the proper circulation of the blood. Unless the blood circulates properly the body cells will not get a sufficient supply of oxygen and the proper growth and development is stopped. This is one reason why smoking is harmful to young people. Smoking stunts their physical and mental growth.

The nerves which control the heart are easily upset by excitement, fear or anger. In a normal, healthy person the heart beats regularly and evenly. If you allow things to upset you, your heart will not pump evenly and serious heart trouble may follow. Do not allow yourself to become over-excited. Do not "lose your head". Keep cool.

Public buildings such as churches, schools or theatres must be kept *ventilated* or supplied with fresh air. Fresh air contains

oxygen. The used air, containing carbon dioxide, should be removed or it will interfere with respiration. Stuffy rooms are unhealthful. Your home should have a constant supply of fresh air. Air containing the carbon dioxide which you have exhaled should be removed. You can ventilate your home by opening the windows (Fig. 79).

All Animals Require Oxygen. Land animals such as mammals, birds and reptiles receive their supply of oxygen very much

Fig. 79.—How to Ventilate a Room
Notice that the window is open at the top as well as at the bottom.

as you do. They have lungs which enable them to take the oxygen from the air. They each have a heart and blood vessels. The oxygen is carried to all cells of their bodies.

Fish, however, do not breathe air as you do although respiration is just as necessary for them as it is for you. They must get their oxygen from the air which is *dissolved* in the water.

If the supply of oxygen which is dissolved in the water of a gold-fish bowl is used up the fish will suffocate. They will be unable to respire for lack of oxygen and so will die. It is thus possible to drown a fish by cutting off its air supply.

Fish have no lungs. They have special organs for taking from the water the oxygen which is dissolved in it. These organs are *gills* (Fig. 80). Whenever you have the opportunity of doing so, watch some fish in an aquarium. You will notice that the fish seem always to be gulping water. The water does not enter the stomach of the fish, however, but passes through the gills and then out beneath the gill-covers. Observe that the gill-covers lift each time a gulp of water passes through them. Lift the gill-cover of a dead fish and examine its gills. The layers of scarlet lace-like structures are the gills. The netted threads are the blood-vessels.

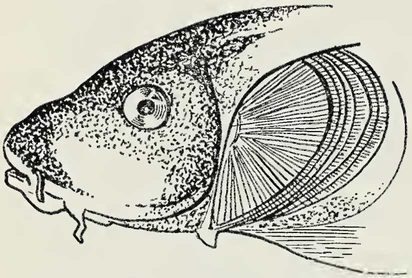


Fig. 80.—How a Fish Breathes
The gill cover has been cut away to show the gills.

Very few of us realize that there is air actually dissolved in water. The reason for this ignorance is that when air is dissolved in water there is no change in the appearance of the water.

You can, however, detect the presence of air in water by means of a simple experiment. Half fill a beaker or glass tumbler with cold water from the tap. Warm it slowly in a sand-bath or warm oven. Do not let it boil. You will observe small bubbles appearing around the sides of the glass. These are bubbles of air.

Plants Require Oxygen. We are often inclined to think of plants as being as lifeless as the earth in which they live. We have this mistaken idea because plants do not move about as

animals do. Plants are living things and, like animals, they require energy to do their work of living. Animals, however, require more energy than plants because they move from place to place.

Since plants require energy to live is it possible that they respire as animals do? Do they use the oxygen of the air? If they do so they will require oxygen in order to live and will die for the lack of it just as animals die. Is it possible to smother a plant? Try this experiment to see if it is possible.

Secure two wide-mouthed bottles (Fig. 81). Provide one of them with a tight-fitting cork. In each bottle place some moist blotting paper. On the blotting paper in each bottle place some bean seeds which have been soaked for a day in water. Cork one of the bottles tightly and leave both of them in a warm place until the seeds start to sprout. Examine the bottles from time to time. You will find that the seeds which could get a plentiful supply of fresh air are growing quite well, while the seeds in the corked bottle died after they had barely sprouted. *Plants respire and will die for lack of oxygen.*

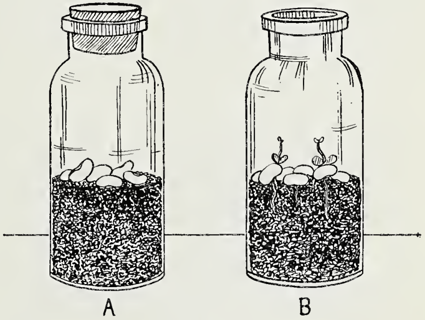


Fig. 81.
Plants require air in order to grow.

New Air for Old. You are possibly wondering when the present supply of the earth's oxygen will be used up since both plants and animals are continually using it and all the fires the world over require oxygen to keep them burning. You may also be wondering why the amount of carbon-dioxide in the air

does not increase to such an extent that breathing will become difficult. You need not fear that the supply of oxygen will be used up or that you will be smothered with carbon dioxide. As carbon dioxide is very valuable to plants as food, they can consume as much carbon dioxide as they can get.

You have already discovered that wood is principally carbon. When you consider the amount of carbon which must exist in the forests of the earth you will realize that there is not enough carbon in the soil to provide the plant with all it needs. Plants must obtain carbon from some other source. This source is the air. Plants absorb carbon dioxide from the air by means of their green leaves. *They use the carbon of the carbon dioxide and return the oxygen in it to the air.* The carbon is used by the plant in the manufacture of sugar, starch, wood and other plant substances.

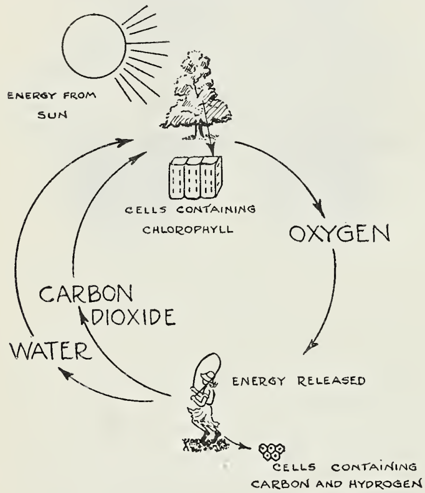


Fig. 82.—The Carbon-Oxygen Cycle

The respiration of animals and plants alike is constantly uniting carbon and oxygen and forming carbon dioxide. It is the process of respiration which sets free the energy they need to keep them living. Green plants are constantly absorbing this carbon dioxide into their leaves. They separate the carbon and oxygen in it. This separating of carbon and oxygen uses up energy. The energy which is needed to do

this is obtained from the sunlight which falls on the plant leaves. Sunlight is one form of energy. It is the energy which the plants use. Green plants must have plenty of sunlight or they will be unable to obtain sufficient carbon for proper growth.

The process of respiration which produces carbon dioxide and the process which plants use to break it up again into carbon and oxygen form an endless cycle. This cycle is called the *Carbon-Oxygen Cycle* (Fig. 82). It keeps the proportion of oxygen in the air practically always the same.

Just as animals which live in the water must obtain their oxygen from it, so also water plants must obtain from the water the carbon dioxide that is dissolved in it. How did the carbon dioxide get into the water? Were it not for the water plants the fish and other forms of water life would soon use up all the dissolved oxygen. Water plants are constantly renewing the oxygen supply in the water. They are using up carbon dioxide in doing this. Water animals are supplying the plants with the necessary carbon dioxide. The Carbon-Oxygen Cycle goes on in the water as well as in the air.

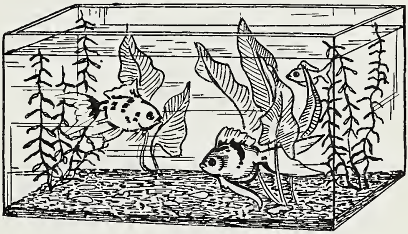


Fig. 83.—A Balanced Aquarium

Can you explain why this is called a balanced aquarium?

Examine carefully the picture of the goldfish aquarium (Fig. 83). The water in this aquarium does not need to be changed. Why? Such an aquarium as this is called a balanced aquarium.

Guide Words

breathe	bronchial tubes	inhale
suffocate	air-sacs	exhale
trachea	lungs	balanced aquarium

tissues	energy	cells
microscope	respire	veins
heart	oxygen	dissolved oxygen
arteries	blood	carbon-oxygen cycle
protoplasm	corpuscles	carbon dioxide
respiration	capillaries	

Signpost Sentences

1. You cannot live without .... from the air.
2. You obtain your oxygen from the air when you ....
3. The oxygen is transported by the circulation of the .... to all parts of the body.
4. Cells contain a jelly-like living substance called ....
5. Protoplasm is the living part of the body ....
6. Protoplasm requires .... to carry on its living processes.
7. .... is the power to do work.
8. Protoplasm obtains its energy by the combining of the carbon in it with ....
9. Energy is released in the .... of the body as heat, as energy of movement and as nervous energy.
10. The .... which is produced during the process of releasing energy is carried by the blood back to the ...., from where it is exhaled.
11. Plants as well as animals ....
12. Green plants can use the .... of the air and with the aid of sunlight can convert it into sugar. Oxygen is set free by this process.
13. The uniting of carbon and oxygen by respiration and of freeing the oxygen once more by plants is called the ....
14. In a .... water animals use up dissolved oxygen and return carbon dioxide to it. The water plants use up this carbon dioxide and return .... to the water.

Questions on the Chapter

1. Name the passages through which air travels on its way to the lungs.
2. How could you show that you exhale carbon dioxide?
3. Of what are body tissues made?
4. What is the difference between respiration and breathing?
5. Why do living things respire?
6. By means of a diagram show how oxygen gets to all cells of the body and how the carbon dioxide from the cells reaches the lungs.
7. Of what use are the red blood-corpuscles?
8. What is energy?
9. What kinds of energy are set free by the respiration of living cells?
10. What kinds of energy are set free when fuels burn?
11. How do you know that plants respire?
12. How is the supply of oxygen in the air maintained?
13. Draw a diagram to illustrate the Carbon-Oxygen Cycle.

Special Problems and Practical Applications

1. In what way are all living cells alike?
2. Plan an experiment to show that growing plants produce carbon dioxide.
3. Why is pure oxygen sometimes given to patients in hospitals?
4. Should a house be ventilated in winter as well as in summer? Give reasons for your answer.
5. How do men submerged in submarines obtain the air necessary for breathing?
6. You have heard of the ''Black Hole of Calcutta''. Why did so many of the prisoners in it die?
7. If your school is provided with a microscope examine cells such as are found in a drop of blood or in an onion skin.
8. Why is it so important to stop bleeding from arteries and veins?
9. By referring to first-aid books learn how bleeding from cut arteries and veins is stopped. What is a tourniquet? Why is a tourniquet placed *below* a cut vein and *above* a cut artery?
10. Why should a tourniquet not be left on too long?
11. Why is it necessary to ventilate rooms in which you live?
12. Describe how you would ventilate a room in your home.
13. Tell how to make a balanced aquarium.
14. Explain why seeds will not sprout in wet, soggy soil.
15. From a first-aid manual learn how to revive the apparently drowned. Demonstrate to the class how you would proceed in such a case.
16. Read the life of William Harvey, the discoverer of the circulation of the blood.

Home Projects

1. Germinate seeds by placing them on moist blotting paper: (a) in the open, (b) in a corked bottle. Notice which grows the better.
2. Place a saucer of lime-water on a window sill. Leave it there for several days. Explain the reason for the change in the lime-water.
3. Plants can produce the green colouring matter in them only while in the sunlight. Place some growing plants in a dark cupboard. Examine them after several days. What change has taken place in them.

UNIT IV

HOW WE DEPEND UPON PLANTS FOR FOOD, SHELTER AND CLOTHING

CHAPTER X

PLANT LIFE

Can you answer these questions?

1. Does any of your daily food come from the air?
2. How does sunlight help to manufacture your food?
3. How does a seed become a plant?
4. Are seeds alive?
5. What animals would be able to exist if there were no plants?
6. Why do plants have flowers?

A Dreary World. Suppose you lived in a world in which there were no plants. It would be a strange world. You would miss the gardens and the fields which produce beautiful flowers and food for you and for the cattle which furnish us milk and meat. It would be impossible to live in a world lacking these things. Your food, your shelter and your clothing depend upon plant growth. You will recall that the continued supply of oxygen in the atmosphere depends upon plants, as plants renew the supply of oxygen in the air. With these facts in mind you will be interested in knowing more about plants.

A Large Family. There are many different kinds of plants. If you were to make a list of all the different kinds of plants in your neighbourhood, such a list would be but a small fraction of the kinds of plants found in the world. These plants vary in size from the giant Douglas fir to the tiny clover and from the

stately oak to the creeping vine. What have they in common that causes them all to be classed as plants?

A plant is a living thing. Living things grow, they require food and they reproduce their kind—they produce other living things like themselves. All the living things in the world are divided into two great classes. They are either plants or animals. Both plants and animals are built of cells (see Chapter IX). The chief difference between the cells of plants and the cells of animals is that the plant cells have walls of cellulose (wood), while the animal cells have walls usually made of a thin skin-like substance called *chitin.* There are other differences. Living animals are usually very active. They move about. Living plants as a rule never move from one place to another. They remain fixed in one place. Plants, like animals, need water, air and food to live and grow. However, a plant's methods of securing these things are different from those of animals. Moreover, since plants are unable to move they must depend upon food and water coming to them. Because of this fact many plants have developed means of storing food and water.

Fig. 84.—The Parts of a Tree

Under the ground each plant has a "root system" by which the plant absorbs from the soil water containing dissolved mineral salts. This root system helps to anchor the plant. With many plants the roots also serve as a storehouse for food.

In the air the plant spreads its crown or leaf system. This leaf system enables the plant to secure food from the air. In the leaves the plant, with the aid of sunlight, manufactures its

food. Connecting the roots and the crown there is usually a stem. The stem gives support to the crown and carries water upwards from the roots and carries manufactured food downwards from the leaves.

First Hand Knowledge. In order that you may study and compare them, procure a grass plant, a buttercup plant, a carrot and a willow. Remove carefully the soil from their roots and wash away all the soil particles. Examine the grass roots with a magnifying glass. You will observe that they become smaller as you follow them away from the plant. If you look closely you will see very fine, small threads growing upon the smallest rootlets. These are called *root hairs* (Fig. 85). It is by means of these tiny root hairs that the plant absorbs from the soil its water and the dissolved mineral salts. Can you find root hairs on each of the other root systems? Root systems like those of the grass, the buttercup and the willow are *fibrous root systems* (Fig. 86). Those like the carrot are *tap roots* (Fig. 86). Tap roots, besides securing water and mineral salts for the plants, store food as well.

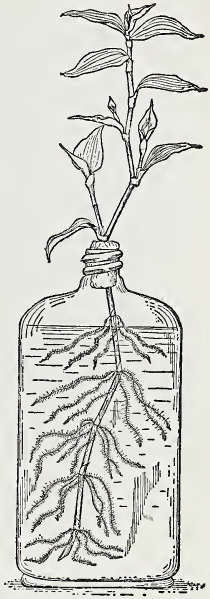


Fig. 85.—Cutting of Wandering Jew in Water

Showing root hairs which increase the absorbing surface.

Plants Manufacture Food. Besides the soil, plants have another source of food supply. They are able to absorb carbon dioxide from the air. They use the carbon dioxide to manufacture sugar. Sugar is a food which plants are able to convert or change into a great many useful substances such as starch, cellulose and oils. The carbon dioxide is absorbed through tiny pores or openings which are more abund-

ant on the under side of the leaves. With the aid of sunlight the absorbed carbon dioxide joins with some of the water which comes from the roots. Sugar is formed as a result. From the process which we have just described the oxygen of the carbon dioxide is given back to the air. To separate the oxygen from the carbon dioxide in this way a great deal of energy is required. The sunlight supplies this energy. Therefore the leaves of the plant must be exposed to the sunlight as much as possible (Fig. 87). If you examine a number of growing plants you will see that the leaves are placed on the stem in such a way that each is exposed to the sunlight and that each shades its neighbour as little as possible.

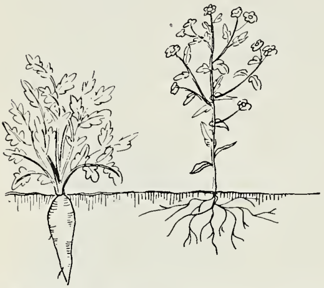


Fig. 86.—Tap Root (Left) and Fibrous Root (Right)

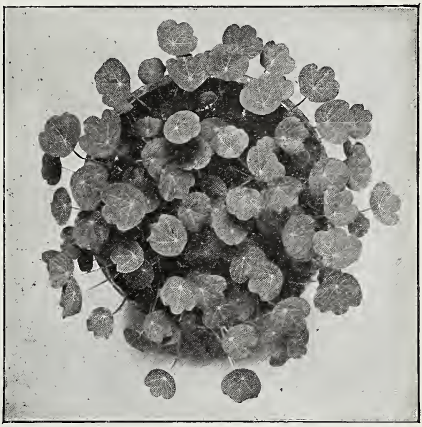
How Water Travels from the Roots to the Leaves. The business or *function* of the stem of the plant is to support the leaves in the best position for obtaining sunlight. The water and mineral salts which the plants absorb from the soil must be carried to the leaves through the stems. In the stems there are bundles of fine tubes called *water-ducts.* You can easily see these water-ducts in a stem of celery. The strings which pull out when the celery is broken are water-ducts. These water-ducts are strengthened by tough wood-fibre cells. In trees the water-ducts dry out and harden and form wood. The newest of the water-ducts are found under the bark. If you cut the willow stem across with a sharp knife you will find the wood-fibre and water-ducts.

The water-ducts pass from the stem into the leaves. The *petiole* (Fig. 88), or stem of the leaf, contains water-ducts which branch from the *midrib* and *veins* to all parts of the leaf. In this way all parts of the leaf obtain the necessary water and mineral salts.

The sugar which is manufactured in the leaf is dissolved in

water and forms sap. The sap travels through the stem to all parts of the plant through other tubes called *sap-ducts*.

The oldest living things on earth today are trees. There are giant cedars in British Columbia which have been growing for more than one thousand years. The age of a tree is to be found by counting the *annual* rings it has (Fig. 89). Each spring a tree produces a new growth of water-ducts just under the bark. This growth forms a new ring around the tree. We call it an *annual ring*. Examine the willow stem. You can tell its age by counting the annual rings.



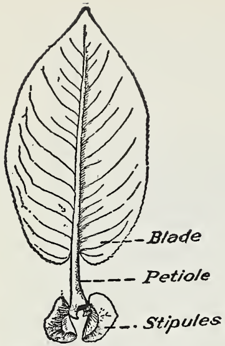
From Gager's Fundamentals of Botany

Fig. 87.—Leaf Exposure to Light

Note that the leaves are arranged in such a manner as to permit all leaves to obtain sunlight.

Let us see now how the plants reproduce themselves.

Providing for the Future. Most plants reproduce by means of seeds. The seeds are usually produced by flowers. To understand this more clearly examine a flower. If possible secure the flower of a buttercup. Examine it carefully. You will observe that it has several distinct parts. As you study the parts you will see that each serves a special purpose. Pull off the five small green leaves at the base of the flower. They are called *sepals*. Together they form the *calyx*. They have served as a covering for the flower when it was a bud. Just above the calyx are five waxy, yellow *petals*. They form a cup which is called the *corolla*.

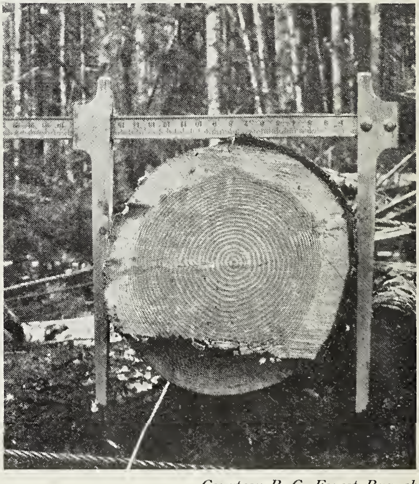


From Gager's Fundamentals of Botany

Fig. 88.—Parts of a Leaf

Remove the petals carefully and you will see attached to the stem a number of *stamens*. Each stamen has two parts. The thread-like stem is called the *filament* and the yellowish head is called the *anther*. The anther produces a fine, yellow powder called the *pollen*. Remove the stamens. There remains at the end of the stem a group of *pistils*. Each pistil is a bottle-shaped body. The enlarged bottom part of the pistil is the *ovary*. It contains the undeveloped seeds which are called *ovules*. The narrow neck above the ovary is called the *style*. The style ends in a sticky head which is called the *stigma*.

The ovules are not seeds. They become seeds when they are *fertilized*. The pollen from the stamens must be carried to the pistil. Here it is deposited on the sticky stigma (Fig. 91). The pollen grain then breaks open and produces a long fine tube which passes down through the



Courtesy B. C. Forest Branch

Fig. 89.

When the tree was cut down it had been growing for fifty years. How was this fact determined?

style and into the ovule. Part of the contents of the pollen grain then mixes with the contents of an egg cell in the ovule. The ovule is then said to be fertilized. When this has happened the ovule develops into a small plant called an *embryo plant*. This embryo plant is a seed.

When the pollen grains reach the stigma of a flower we say that the flower is *pollinated*. The corolla helps the flower to become pollinated. Its bright colour attracts bees and other insects to the flower to obtain the sweet nectar secreted or poured out by the small *nectaries* or lumps at the base of each petal. The insects in travelling from flower to flower rub against the stamens and become covered with pollen. Some of the pollen drops from the insects to the stigmas of the pistils as the insect goes on his rounds. Insects are the chief pollen carriers (Fig. 92). There are also other ways of carrying pollen. Can you detect some of these other ways by studying other flowers?

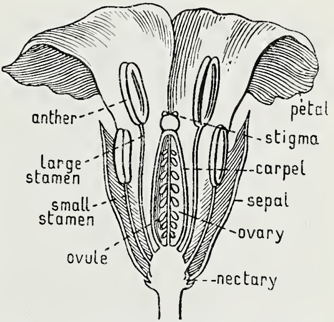


Fig. 90.—Sections of a Typical Flower, Showing Flower Parts

A great many plants produce one crop of seeds in a summer and then die off. Plants which do so are called *annuals*. Wheat, corn, peas, asters, tomatoes are annuals. Many other plants require two summers to produce seeds. When the seeds are ripe the plants die. Plants which require two summers to produce their seeds are called *biennials*. Carrots, turnips, onions, tulips are biennial plants. Other plants live year after year and produce a new crop of seeds each summer. They are called *perennials*. Roses, apples, willows, cedars, firs, oaks are perennials.

Sowing the Seed. The problem of plant reproduction does not end with the development of the seeds. The seeds must be

scattered and planted in suitable places. If the seeds were to fall too close to the parent plant they would not grow into healthy plants because they would be crowded too closely together. They would rob each other of food and sunlight.

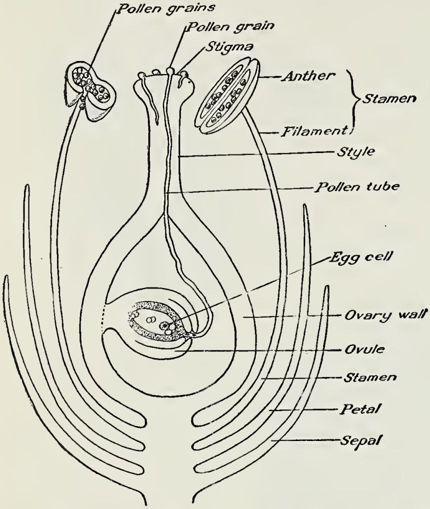


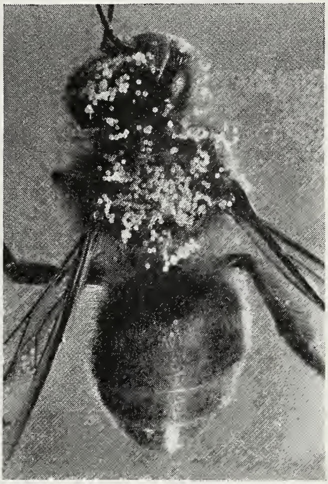
Fig. 91.—Fertilization of an Egg Cell in an Ovule

Seeds are scattered in many ways (Fig. 93). Such seeds as those of poppies are very small and are easily blown by the wind. Dandelion seeds and cotton seeds have *parachutes* of fluff. The maple seed has what might be called aeroplane wings. The burdock seeds are armed with hooks with which to cling to the fur of passing animals. Animals assist in scattering certain other kinds of seeds. Because of their fleshy fruits the cherry, apple and blackberry attract animals and birds. The animals carry the seeds away with the fruit.

Inside the Seed. You may have wondered while you were picking a bouquet of sweet peas what magic made the little black seeds develop into flowering plants? Why should the withered seeds unfold into growing green plants after they have been buried in the soil?

Secure some bean seeds and plant a few in a box containing moist, fertile soil. Place the box on a window sill where it will

be in the sunlight. Place a few of the seeds between moistened blotting papers on a plate. Cover the blotting paper with a saucer. Set the plate aside for a few days. Be sure to keep the blotter moist. Soak some of the seeds in water overnight to soften them. They can then be opened easily.



Courtesy Cornelia Clarke

Fig. 92.—Honey Bee with Pollen Grains

With a needle open and remove the outside skin or *testa* of a softened bean seed (Fig. 94). Examine the testa. Note the scar upon it. This scar is a mark left by a short stem which attached the seed to the bean pod or ovary. Examine the seed. There are two parts to it. Separate carefully the two halves of the seed but do not break them apart. Notice that each half is attached by a short stem to a tiny plant hidden between them. By finding its leaves, stem and root convince yourself that this tiny growth is really a plant. A magnifying glass will help you in this. A tiny plant such as this is an *embryo* plant. Its parts are very simple but they have each a special name. The root, or *radicle,* is attached to the tiny leaves, or *plumules,* by a short stem. The two halves of the bean seed are really special leaves. They are *cotyledons* or *seed leaves.* They contain stored food which the embryo plant uses when it begins to grow.

Each day examine the bean seeds which you put upon the moistened blotting paper. Notice when they begin to *sprout* or

germinate. The embryo plant is then beginning to grow. It is being fed by the food stored in the cotyledons. Moisture and warmth are necessary to start its sprouting. When once it has begun to sprout it continues to grow. It cannot go back to the *dormant,* or resting stage in which it was while it was a seed. Now observe (Fig. 96): (1) where the radicle first breaks through the testa; (2) what causes the testa to break open; (3) what becomes of the testa.

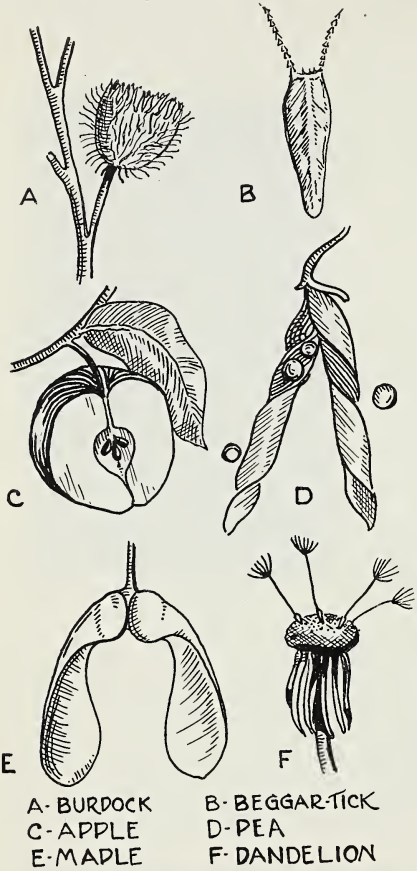


Fig. 93.—How Plants Scatter Seeds
Can you tell how each type of seed is scattered?

Examine the box of earth which contains the seeds. Observe the plumule as it begins to break through. Notice, also, how the cotyledons gradually come to resemble ordinary leaves.

In every seed there is an embryo plant which re-

quires warmth, moisture and air to make it start to grow. Within every seed there is food stored to feed the young plant until it is strong enough to fare for itself. Not all seeds, however, have two cotyledons like the bean. To see this, sprout different kinds of seed. Try to discover some which are like the bean and some which are unlike it.

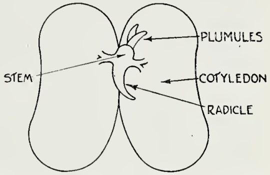


Fig. 94.—Bean Seed Opened to Show the Embryo Plant Within

Making a Garden of Your Own. Your garden should be planned and cultivated carefully. What you have already learned about plants and the needs of plants should help you to make it a success. You should decide which kind of plants you wish to grow and then you should learn how to plant them and when to plant them. You can get a great deal of helpful information from seed catalogues. Successful gardeners who live near you will also be glad to give you advice.

You must first prepare the soil. Examine the place where you intend to have your garden. Is the soil a good loam? If not, what must be added to make it suitable—clay, sand or humus? The soil should be well spaded to allow the air to mix through it. If the soil is too wet it may be necessary to drain it. Free the soil of weeds by digging well and raking it.

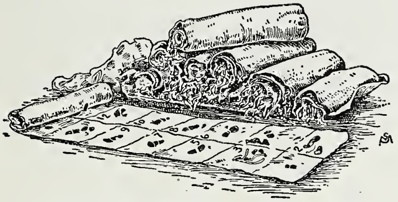


Fig. 95.—A Rag-Doll Seed Tester
Seeds can be germinated in a moistened cloth as shown.

When the soil is prepared you should plan the order in which you are going to plant the seeds. You should also decide where you are going to plant the different kinds of seed. It is a good

plan to divide your garden into beds with pathways between them, so that you may reach all beds easily. The soil in the beds should not be more than two inches above the pathways, for if the soil is high the edges of the bed will dry out in hot weather. The seeds should be planted in moist soil at a depth of about three times their length. If the seeds are planted too deeply the supply of food in the seed is used up before the plumules reach the surface. The young plants then die before they are able to take care of themselves.

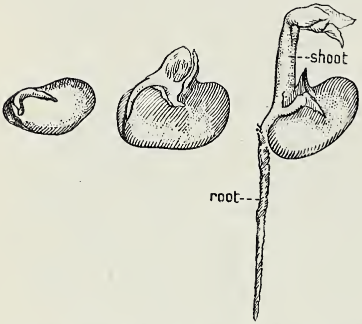


Fig. 96.—Stages of a Germinating Bean

The soil should not be watered too often previous to the appearance of the young seedlings above the ground. It is better to water the garden well every four or five days than to sprinkle it every day.

With a rake or a hoe you should regularly mulch or stir up the soil between the plants. Cultivating the soil keeps the top soil loose, lessens the loss by water evaporation and keeps wild plants or weeds from growing.

Soil usually contains seeds of wild plants. These seeds produce seedlings which grow into very hardy and persistent weed plants The weeds must not be allowed to gain headway, or they will rob your garden plants of water and mineral salts and will shade out the sunlight. They will also prevent the free circulation of air among your plants. It will be necessary to remove by hand the weeds which grow close to your plants.

As your garden plants develop it may be necessary to thin them out. Some of them must be pulled out to allow the remaining ones room to grow properly.

From Gager's Fundamentals of Botany

Fig. 97.—Sprouting Mustard Seeds

The seeds are growing on moist blotting paper. Notice the abundance of root hairs.

GUIDE WORDS

reproduce	stigma	sap-ducts
cells	sugar	wood-fibre
cellulose	annual	annual rings
chitin	stamen	testa
root system	ovary	scar
crown	pores	embryo
root hairs	energy	petiole
style	water-ducts	biennial

pollen	petal	filament
sunlight	radicle	anther
perennial	plumule	pistil
flower	germinate	plants
sepal	corolla	seeds
calyx	cotyledons	

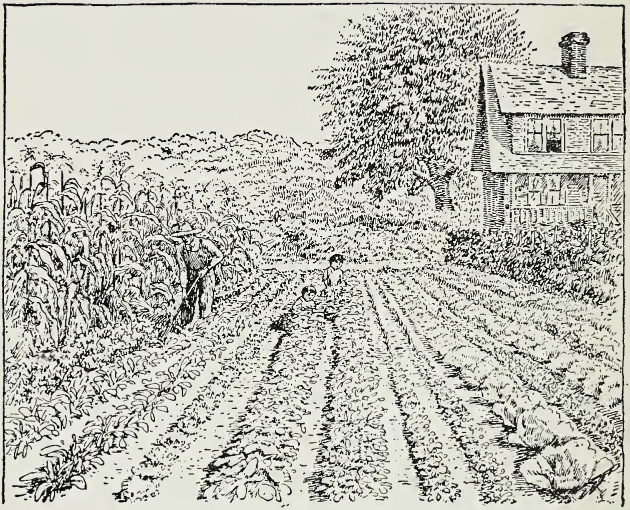


Fig. 98.—A Productive Garden

Signpost Sentences

1. Animals depend upon .... for all their food.
2. Animals depend upon .... indirectly for their oxygen.
3. Plant .... absorb water and mineral salts from the soil.
4. Green leaves absorb carbon dioxide from the air and with the aid of .... change it into sugar.
5. Each year a new layer of .... grows under the bark of trees. This layer is called an .... ring. The age of a tree can be discovered by counting the ....
6. Most plants reproduce themselves by means of ....
7. The chief purpose of a .... is to produce seeds.
8. A seed contains an .... plant.
9. Moisture and warmth cause seeds to ....

Questions on Chapter X

1. Tell of as many ways as you can in which you depend upon plants.
2. What are the three ways in which living things differ from non-living things?
3. Of what use to the plant is (a) the root (b) the leaf (c) the stem?
4. What are water-ducts?
5. What do plants require in order to manufacture sugar in the leaves?
6. Name and tell the use of each part of some flower you have studied.
7. Of what use are insects to plants. Name some insect which is particularly useful to plants.
8. How deep should seeds be planted? Why?
9. How do each of the following plants scatter their seeds: poppy, burdock, peas, dandelion, thistle, maple?
10. Name the parts of a bean seed and tell the purpose of each part.

Special Problems and Practical Applications

1. Explain why seeds which lie in the ground all winter do not germinate before the spring.
2. Make a study of several plants which store food. Tell how each one stores it.
3. Why do such plants as the thistle and dandelion become troublesome weeds?
4. How do tree trunks grow larger each year?
5. What part of annual plants live through the winter?
6. How do plants prepare for early growth in the spring?
7. How do plants prepare for winter?
8. Name several insects which are harmful to plants and tell what harm they do.
9. Why do seeds of wheat, oats and barley make good food for animals?
10. What plants provide fruits suitable for food for human beings?
11. Name several plants which produce fibre suitable for cloth making.

Home Projects

1. Make an egg-shell garden at home by putting half egg-shells in a tray of sand. Put soil in each shell and grow seeds in them.
2. Start a window garden for potted plants. Learn to take care of it.
3. Make a hot-bed for germinating (or sprouting) seed in the spring.
4. Make a collection: (*a*) of wind-scattered seeds; (*b*) of animal-scattered seeds; (*c*) of seeds scattered in other ways.
5. Germinate some corn seeds and compare them with germinated bean seeds (Fig. 95).
6. Germinate some seeds in an airtight bottle in which a small vial of lime-water has been placed. Can you account for the change in the lime-water?
7. Make a collection of seeds and learn to identify them.
8. Germinate a number of seeds from a package to determine what percentage are likely to grow.

CHAPTER XI

TREES

Can you answer these questions?

1. What articles of clothing are made from wood?
2. Are there flowers on a maple tree?
3. Why do gardeners prune trees?
4. How do bees help to produce fruit?
5. Do the leaves fall off evergreen trees?
6. From what is paper made?

Giants of the Forest. Trees are the largest and stateliest of all plants. Many of them are the oldest of all things now living. In our forests are trees which were saplings when Julius Caesar invaded Britain. They were already forest giants when Columbus came to America. The shingles on the roof of your house may have been growing when Cartier sailed up the St. Lawrence. What interesting stories trees could tell if they could but speak.

Man's Supply House—The Forest. The forest trees play many roles in our daily lives. The home in which you live and the furniture you use were hewn from the forests. Many sea-going vessels are fashioned from timber. The paper of this book was made from trees. Things so unlike as artificial silk, paint, sugar, alcohol, vinegar and matches are products of our trees. Rubber is produced from the sap of the rubber tree. Automobile tires, rubber boots, hot water bottles and other articles in daily use are made of rubber.

A tree is a perennial plant. It has a root, a stem and leaves. The stem is made up mostly of woody fibres and dried up water-ducts. Man uses this tough wood-fibre for lumber. The roots and leaves of the tree serve the same purposes as the roots and leaves of all other plants. Trees, like other plants, reproduce

Courtesy Publicity Bureau, Vancouver

Fig. 99.—Giants of the Forest

Forests are beautiful as well as useful.

themselves by seeds. The cherry blossom and the maple flower develop into fruits in which the seeds are found. Like the flower of the buttercup these tree flowers produce pollen and ovules. On many trees the flowers are small and not easily seen. Have you ever seen the flowers on the hazel or birch? Find, if you can, some of these trees and study their flowers.

Courtesy B. C. Forest Branch

Fig. 100.
A virgin forest is both beautiful and valuable.

One great family of trees has *cones*—a special part for producing pollen and seeds. This is the *conifer*, or *cone-bearing* family. Sometimes conifers are called *evergreens*, because they remain green throughout the year. Other trees lose or shed their leaves in the autumn and are bare during the winter. Trees which shed their leaves in this way are *deciduous* trees. The maple, for example, is a deciduous tree. Evergreens also shed their leaves, but do not lose their old leaves until new leaves have grown to replace them. Nearly all evergreens are conifers, or cone-bearing, and nearly all deciduous trees are flower-bearing.

The conifers are the chief source of softwood lumber and of wood-pulp for the making of paper.

A Source of Wealth. Lumbering is one of Canada's chief industries. It provides employment for many people in New Brunswick, Quebec, Ontario, Alberta and British Columbia. Canada's large forests are disappearing. In former days the trees were so plentiful that wasteful methods of logging developed, and now areas once rich in forest wealth are bare (Fig. 102). This waste has led to the establishment of departments of forestry to save the forests which remain.

Courtesy B. C. Forest Branch

Fig. 101.—A Forest Fire

Forests have other uses besides producing lumber. The roots of their trees keep the soil on the hillsides by preventing it from being washed away. This saves the underground water. In parts of the country where there is not a great deal of rainfall the land soon becomes parched if the forests have been cut down. The hillsides become bare and the top soil is washed away.

During the rainy season there are floods because all the rain goes into the rivers as run-off water. In forested areas, because the water seeps into the ground, the flow of water is checked and the streams do not rise in great floods.

Conserving the Forests. As the country becomes more settled, people use their forests for recreation. Much pleasure is to be had from camping and roaming in them. As population increases wild life becomes scarcer and the forest is a refuge for this wild life.

Courtesy B. C. Forest Branch

Fig. 102.
This unsightly burned-over hillside was once a beautiful forest.

To replace the disappearing forests much has been done by *reforestation*: large areas of country not suitable for farming have been put to use by planting seedlings of trees upon them. By these young trees bare hillsides are being transformed into beautiful new forests.

One of the problems of forest conservation is the prevention and fighting of forest fires (Fig. 101). Many forest fires are caused

by carelessness. The camper who leaves his camp-fire before it is out, and the smoker who throws away his lighted match or cigarette, have caused many destructive fires.

Trees furnish other useful products besides lumber. Medicines and nourishing foods come from trees. The cascara bark from our Canadian woods produces a well-known medicine. The bark of the oak, of the hemlock and of other trees contain tannin which hardens leather and preserves it. The bark of the cork

Courtesy B C. Forest Branch

Fig. 103.

If protected from fire this logged-over area will again produce a forest.

oak is used for making corks for bottles. From the sap of the maple tree maple sugar is obtained.

Some trees are prized for their beauty. The dogwood, the elm, the horse chestnut and the maple beautify our homes, our boulevards and our parks.

However, it is for their fruit that we appreciate our trees most highly. Not only does fruit contain nourishing food but it gives variety and zest to our meals.

Orchard Science. The cultivation of fruit trees is a pleasant

branch of farming (Fig. 104). The Annapolis Valley of Nova Scotia, the Niagara Peninsula in Ontario, and the Okanagan Valley of British Columbia are famous for the fruit grown in them.

To develop and manage an orchard requires knowledge and skill. To select a suitable site is the first step. In choosing the site one must consider the nature of the soil, the amount of wind which blows there, the possibility of late frosts in the spring and

Courtesy, Dept. of Immigration and Colonization, Ottawa

Fig. 104.—An Orchard in Bloom.

of early frosts in the autumn, the amount of rainfall and the possibility of obtaining water for irrigation, and the kind of fruit to be grown. If there are no natural forests or hills to protect the orchard, wind-breaks or rows of trees such as the poplar should be planted at the same time as the orchard is planted. A wind-break prevents the snow from being blown away and so lessens the danger of damage to the roots from winter frost. It also protects the blossoms and fruits from violent winds.

A farmer starting an orchard may obtain advice from the Department of Agriculture as to the best kinds of fruit to grow.

No orchard can be a good one unless it receives constant care and cultivation. Cultivation destroys the weeds which would crowd the roots of the trees. In some regions cultivation is necessary to conserve the moisture in the soil. This moisture is constantly evaporating. It reaches the surface by capillary attraction and evaporates there (See Chap. V). This loss may be prevented to a large extent by the proper cultivation of the soil. The mulching, or breaking up, of the top soil keeps the water from reaching the surface easily. This helps to retain it in the soil. Experiments have shown that at least thirty per cent of the soil water can be saved by mulching the soil to a depth of three inches twice a week.

On a hot day a single apple tree will give off as water vapour about fifty gallons of water. An orchard, therefore, has a great need of water. In localities where the rainfall is small and the ground water is scarce irrigation is practised. Water is brought by flumes, or ditches, to the roots of the growing trees. The flow of the water is carefully regulated. If the tree receives too much water the roots will not spread out nor strike deeply into the soil. As a result they do not get a sufficient amount of mineral salt for the tree.

As the orchard grows, pruning, or cutting back, of the trees is necessary. Some of the branches are cut off to allow more food to reach the fruit. This makes the fruit larger and better. Trees are also pruned to "shape" them. This allows them to resist the wind better, and permits the fruit-picker to reach the fruit more easily.

The grower of fruit trees must provide for the pollination of the blossoms in the spring. To do this he must know which insects to protect and which to destroy. The most useful friend of the orchard is the bee. This industrious worker hastens from flower to flower seeking nectar with which to make honey. As it flies from flower to flower it spreads the pollen which fertilizes the blossoms. These fertilized blossoms grow into fruit. Fruit growers frequently keep hives of bees in their orchards.

Guide Words

forest fires	conifers	orchards
lumber	fir	wind-break
pollinated	spruces	hemlock
cedars	cones	agriculture
pines	forestry	irrigation
deciduous	reforestation	pruning
evergreen	conservation	wood-fibre
seeds	trees	

Signpost Sentences

1. The largest and oldest of all living things are ....
2. .... of trees is very useful to man for lumber and pulp.
3. Trees are reproduced by ....
4. On many .... trees the flowers are small and hard to see.
5. In .... trees, the seeds are produced in cones.
6. Conifers are .... by means of wind.
7. .... trees shed all their leaves each autumn.
8. Governments maintain Departments of Forestry for the protection and .... of forests.
9. Carelessness has been the cause of many ....
10. .... provide many valuable foods, medicines and other useful materials.

Questions on Chapter XI

1. Name some useful articles made from lumber.
2. What useful products are manufactured from the sap of trees?
3. What foods do we obtain from trees?
4. Name some valuable medicines extracted from trees.
5. What part do trees play in spreading the news of the world?
6. What textile is manufactured from the wood of trees?
7. Why are wind-pollinated flowers usually not very showy?
8. Tell why forests should be conserved.
9. State three reasons for planting ''wind-breaks'' near an orchard.
10. Why should the soil in an orchard be cultivated?
11. What advantages are gained by pruning trees?
12. Why are insects necessary before a good crop of fruit can be produced?

Special Problems

1. Why are fruits valuable foods?
2. On an outline map mark the chief fruit growing areas of Canada. Name the kinds of fruit especially grown.
3. By reference to an encyclopaedia find what European countries have for a long time been practising forest conservation.

Practical Applications

Make a survey of the lumber industry of Canada according to the plan given below. Much information can be obtained from the Canada Year Book and the encyclopaedia.

Forest Trees:	1. Hardwoods—Maple, Walnut, Birch, Hickory.
	2. Softwoods—Fir, Pine, Cedar, etc.
Logging:	1. Eastern Canada—Small timber—Hand logging.
	2. Western Canada—Machine logging.
	3. Logging Camps.
Transportation:	1. River Drives.
	2. Rafts and Booms.
	3. Railroads.
Saw Mills:	1. Rough Lumber, logs, poles.
	2. Finished Lumber, flooring, veneers.
	3. Sidings, shingles.
	4. Seasoned Lumber—sun dried. dry kilns.
Sale of Lumber.	

CHAPTER XII

ENEMIES IN THE ORCHARD

Can you answer these questions?

1. How do insects damage orchards?
2. How do "worms" get into apples?
3. How do farmers destroy insect pests?
4. Are butterflies harmful insects?
5. Will small butterflies ever grow to be large ones?
6. How do butterflies live through the winter?
7. How do maggots get into meat?
8. Do plants "catch" diseases?

A Strange Transformation. While the bee is a friend of the orchard man there are other insects which are his enemies. The fruit-grower must be on guard against these insects. They prey upon his trees and fruit. To fight them successfully he must study their life histories.

If you study the life history of an insect you will learn that it seems to lead a "double life". You probably dislike caterpillars and cabbage "worms". Yet these caterpillars and cabbage worms become butterflies and moths. You have seen maggots crawling through rotting meat. These maggots are baby house-flies which some day may crawl into your milk bottle.

The Life Story of an Insect. Insects, as a rule, go through four life stages (Fig. 105). They begin life as *eggs*. In the second stage we find the eggs have hatched into *larvae,* or small worm-like creatures. Grubs are larvae which later become beetles; maggots are larvae which become two-winged flies; caterpillars are larvae which become butterflies or moths. Smooth caterpillars become butterflies; hairy ones become moths. The

larval stage of an insect is the growing stage. It is at this time that many insects do their greatest damage to the trees. Caterpillars, for example, have tremendous appetites and will strip the branches of a tree bare of leaves.

The third, or the *pupating,* stage, is usually a *dormant,* or sleeping, stage. The larva becomes an inactive *pupa.* During this pupating stage the larva changes completely into the fourth stage, the full sized *adult insect.* Beneath the skin of the pupa as it lies dormant, the wings and legs develop. The shape and build of the body changes. The worm-like larva becomes a full-fledged insect with a *head,* a *thorax* and an *abdomen.* It has three pairs of jointed legs and in many cases has wings.

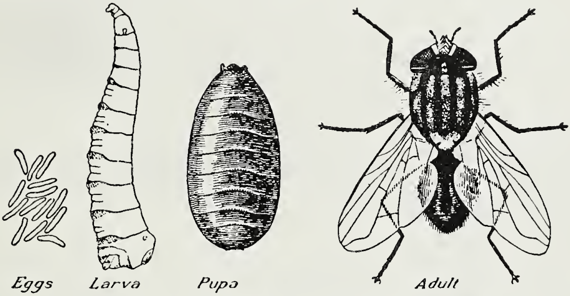
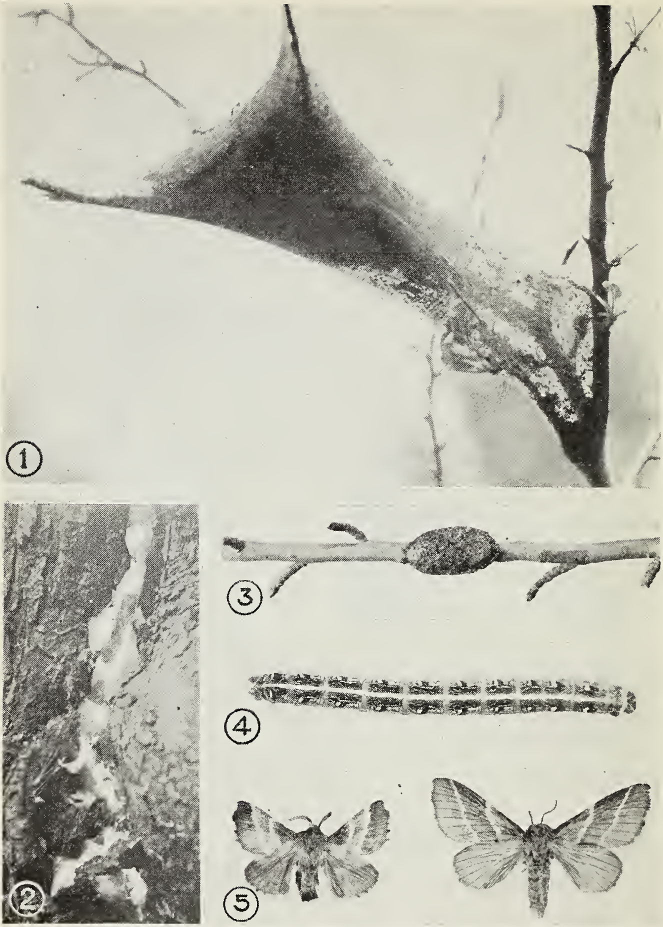


Fig. 105.—Life History of the House Fly

Before caterpillars pupate they spin about themselves a *cocoon,* or covering, of fine silk. The larvae of butterflies do not usually spin cocoons but attach themselves by a silken thread to twigs or leaves. They are protected during the pupating stage by the hardening of the outer skin. Such a pupa is called a *chrysalis.* When the change from the larval to the insect stage is completed, the insect breaks through its covering and emerges as a completely formed adult insect. This change in which the worm-like larva becomes an adult insect is called the *metamorphosis* [1] of the insect.

1 Metamorphosis—change of shape.



Courtesy Entomological Branch, Dominion Department of Agriculture

Fig. 106.—Life History of the Tent Caterpillar

(1) Web on nest of caterpillars. (2) Cocoons on the bark of an apple tree. (3) Egg mass. (4) Mature caterpillar. (5) Male and female moths.

An adult insect, such as a moth of the tent caterpillar (Fig. 106), may appear quite harmless as it flits about. It will soon land on a suitable tree where it will lay a hundred or more tiny eggs. The moth will then die and the eggs will remain unnoticed on the tree all winter. In spring the eggs will hatch into caterpillars, which will destroy vegetation.

Fighting the Insect Pest. You have learned that the feeding stage of the insect is the larval or caterpillar stage. During this stage they are most easily destroyed.

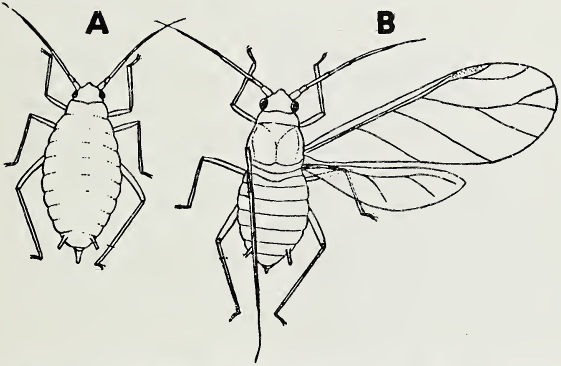


Fig. 107.—Wingless (A) and Winged (B) Forms of the Green Apple-Aphis: Sucking Types of Insects

There are two types of insects which attack fruit trees. One type has jaw-like mouth-parts. An insect of this type, e.g., the caterpillar, will bite off solid food and swallow it. The other e.g., the aphis (Fig. 107), has long and tube-like mouth-parts. With these it sucks the sap of the tree from the leaves or through the bark.

Fruit-growers destroy the biting type of insect by spraying the trees with a poisonous spray. This spray covers the stems and leaves with a thin layer of poison. When the insects feed on this poison they are killed. Arsenate of lead is used for this purpose.

The sucking type of insect, such as plant lice and scale insects, which get their food from the inside of the leaf, can not be destroyed in this manner. They are killed by contact with strong washes, or sprays, of oily or soapy mixtures, often with tobacco extract. Such sprays must be put directly upon the insects. The sprays close up the breathing pores of the insects and they die from lack of air.

The Orchard Pest—The Codling Moth. One of the most harmful insects to the apple-orchard is the codling moth. Figure 108 shows a chart of the life history of this insect. In the spring when the apple flowers are in bloom the female moth lays her eggs at the base of the flower. Soon after the egg has hatched the larva crawls into the flower and there establishes itself. When the petals fall and the fruit begins to develop the larva eats its way down the side of the core and thence works into the fleshy part of the fruit. While tunnelling it spins a web and leaves pellets of waste entangled in it. This makes the fruit unattractive. It also causes the fruit to become stunted and to fall early from the tree. The market value of the fruit is lessened. The apples rot around the injured places and cannot be stored for any length of time. Wormy apples which rot when stored along with good ones cause these also to rot.

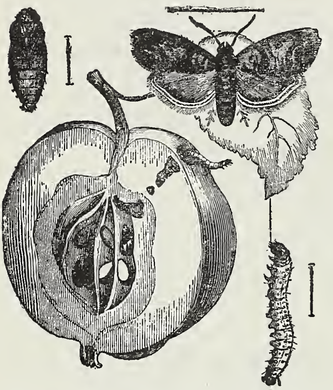


Fig. 108.—Life History of the Codling Moth

The larvae leave the apples before winter comes. They spin a web to lower themselves to the ground or to the trunk of the tree. They spin their cocoons and then pupate under boards or loose bark. If the cocoon is spun before the month of August

the adults will emerge as moths before the arrival of winter and will infect other apples. Insects in cocoons spun after August will remain dormant until the next spring.

A knowledge of the life history of the codling moth enables the orchard-owner to combat it with poisonous arsenic solutions. The spraying must be done before the larva has eaten its way into the young apple but not before the bees have had a chance to pollinate the blossoms. If the spraying is done too soon the bees may be poisoned. If the spraying is done too late the sepals close and prevent the poison from reaching the larva.

The life history of the moth also tells us that it may be checked while in the pupating stage. Birds feed upon the pupae and destroy a great number of them during the winter. Chicadees, nuthatches and downy woodpeckers are natural enemies of the codling moth. They can be encouraged to visit the orchards in winter by hanging pieces of suet on the branches of trees.

Courtesy British Columbia Department of Agriculture

Fig. 109.—Apple Tree Attacked by Black-Spot Canker, a Fungous Disease

Plants Catch Diseases.

The fruit-grower must be on guard both against the insects and against fungus pests. *Parasitic fungi* (Figs. 109 and 112) are very simple forms of plants which grow on other plants or animals. Mildews, moulds, smuts, fire blight, rusts and rot are among the many diseases caused by fungi which attack plants. They weaken or kill the plant, make fruit unattractive, and prevent it from keeping.

Most fungus plants (Fig. 111) grow from tiny dust-like cells

called *spores* and not from seeds. Spores are produced by the fungi in countless millions. They are carried by the wind in every direction. It is desirable to attack a fungus before the spores are produced. This prevents the spread of the fungus. The fungus may also be killed in the early stages of its growth. This is usually done by spraying the plants with chemicals which kill the fungus just as the spores have started to grow.

Courtesy British Columbia Department of Agriculture

Fig. 110.

These trees, three years previous to the taking of this photograph, were diseased like the tree in Figure 109. Spraying and other methods were used to kill the fungous growth, and the trees once more became healthy.

Bordeaux mixture and lime-sulphur[1] are two common sprays used for this purpose. When once the fungus has entered the tree itself, the branch or tree which is infected must be destroyed. This is the only way in which the fungus may be killed then.

Recognizing the importance of preventing and controlling the spread of insect pests and fungous diseases, most governments maintain a Department of Agriculture. Officials of this department inspect plants and fruits imported from foreign countries

[1] Lime-sulphur mixture contains lime, sulphur and water in the proportion of one pound of lime, one pound of sulphur (powder) and five gallons of water. Bordeaux mixture is a solution of copper sulphate (bluestone) in water.

to see that no new diseases are introduced into the country. The fruit-grower can always obtain help from this department.

Friendly Birds. We all like birds for their cheerful songs and bright plumage but few of us realize their value as destroyers of insect pests. A study of the life histories of harmful insects will show you that birds destroy vast numbers of them. Gardeners should be familiar with the habits and varieties of birds most useful in destroying these harmful insects. The thoughtful gardener encourages the birds to stay in his garden. To attract them he provides nesting places and watering devices. During the cold winter weather he scatters breadcrumbs and places pieces of suet where the birds can feed in safety. He is usually well rewarded for his trouble as the birds keep harmful insects in check and lend a charm to the garden or orchard by their songs.

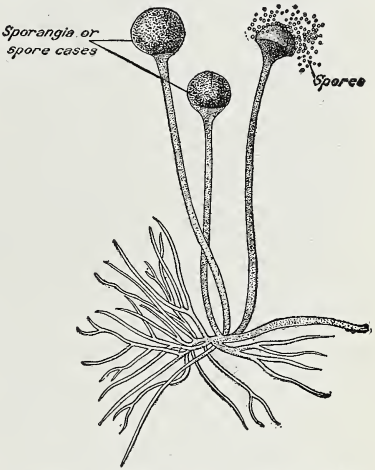


Fig. 111.—Bread Mould (Highly Magnified)
Note the spores which are set free to float about in the air.

We have noted how the chickadee, the nuthatch and the woodpecker (Figs. 113 and 114) keep in check the codling moth. If you watch the antics of these little searchers you will find that they destroy the larvae and eggs of many other insects as well, since birds like insects as food and are diligent in searching for them and catching them for their young.

It is a pleasant hobby to study the bird life of the neighbourhood. One can spend a profitable winter's evening building

bird-houses (Fig. 115) and in devising ways of gaining the friendship of the birds which will return in the spring. Some of these birds will travel thousands of miles away from their winter homes. The humming bird, which builds its nest in the wilds of Northern Canada and the Yukon, in the autumn leads its young to the forests of Brazil. You may have noticed ducks and geese passing overhead on their annual migrations.

Courtesy British Columbia Department of Agriculture
Fig. 112.—Healthy Scale of Lily Bulb (Left) and Similar Scale Rotted by Blue Mould (Right)

There are, however, some hardy birds which brave our winters and do not migrate. On the fiercest winter days the chicadee is to be found searching for his food. He may be seen peeping into the cracks in the bark of trees or hanging upside down pecking for some hidden insect. Few other wild birds are more useful to mankind than he. During the winter he must eat extra food to keep him warm. He eats innumerable insect eggs and small larvae to satisfy his hunger.

Guide Words

chewing insects	parasitic fungi	plant lice
sucking insects	lime-sulphur	birds
arsenate of lead	scale insects	life history
Department of Horticulture	adult insect	pupa
migrations	woodpeckers	chrysalis
	larva	moulds

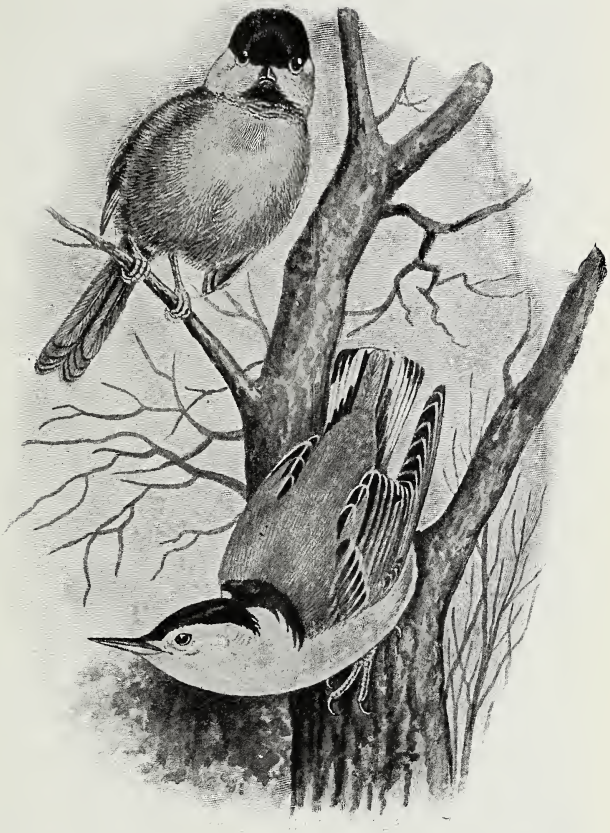


Fig. 113.—Chickadee (Left) and Nuthatch (Right)

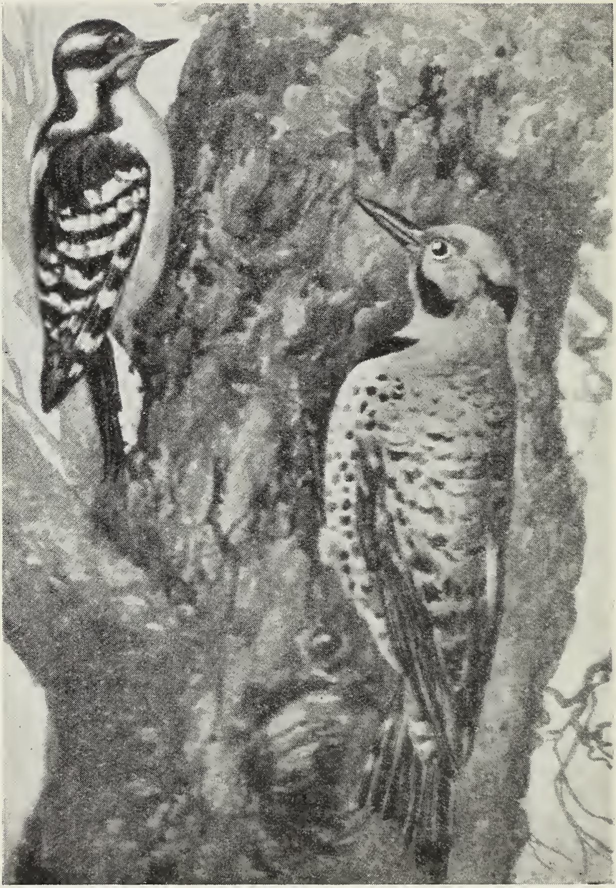


Fig. 114.—Downy Woodpecker (Left) and Flicker (Right)

codling moth	sprays	metamorphosis
chicadee	eggs	dormant
larval	mildews	nuthatches
caterpillar	smuts	plant diseases
spores		

SIGNPOST SENTENCES

1. .... eat the leaves of plants and may be poisoned by spraying the leaves.
2. Strong sprays and soapy mixtures are used to destroy ....
3. Most insects have a .... of four stages.
4. Most of the damage which insects do to plants is done during the .... stage.
5. Moulds and bacteria which cause disease in plants are called ....
6. Moulds are simple forms of plant life which reproduce themselves by means of ....
7. Bordeaux Mixture and .... are effective sprays used to combat fungous diseases.
8. Imported fruits and plants are carefully inspected by government officials to prevent the entry of new .... into Canada.
9. Birds are helpful in checking and destroying ....

QUESTIONS ON CHAPTER XII

1. Name two types of harmful insects.
2. How may sucking insects be destroyed?
3. Name and describe the four stages in the life history of the codling moth.
4. When should apple blossoms be sprayed to destroy codling moths?
5. Why do codling moths lower the value of the fruit they infest?
6. What are the distinguishing features of an insect?
7. What is a chrysalis?

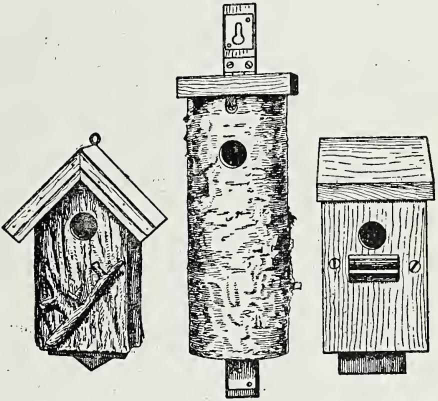


Fig. 115.—Three Types of Bird-Houses

8. Name some parasitic fungi which cause plant disease?
9. What sprays are particularly effective against fungus?
10. Why are birds so useful in combating insect pests?

Special Problems and Practical Applications

1. Study the life history of a mosquito. Write an account of it in your Science Record Book. At what stage of their life history can mosquitoes be most easily destroyed?

2. Make a study of either the stag-beetle or peach borer. Tell how to combat it.

3. Why is the house-fly most dangerous during the adult stage of its life?

4. Give an account of the life-history of a house-fly. Suggest methods which would, if followed, reduce their number.

5. Name some insect pests which are to be found in your neighbourhood.

6. The "silk-worm" is the larva of an insect. Study the life history of this insect and report to the class as follows:
   - (a) Where the insect is grown.
   - (b) What plant is used to feed the larvae.
   - (c) How the silk-worm produces silk.
   - (d) How the silk is obtained from the silk-worm.
   - (e) The appearance of the adult insect.

7. Procure a book or a government pamphlet on bee-keeping. You will find that these interesting insects work and live together in communities. Give an account of this to the class.

8. The ant is another community worker. Learn how ants live and work together.

9. Why should meat be kept in a "meat safe" which is provided with screened sides? What is "fly-blown" meat?

Home Projects

1. Make a collection of butterflies and beetles and mount them on pins in a specimen box. Try to learn which of the insects you have collected are harmful pests.

2. If you grow roses at home examine them carefully to see whether or not they are infested with insect pests. A common enemy of the rose is the *aphis* (plural aphides), small green insects, often called plant lice. Consult a florist to find out how aphides may be destroyed. Rose leaves often become infected with mildew. The florist will tell you how this disease may be treated.

3. Collect large caterpillars from trees and place them together with some leaves of the tree on which they were found in a quart sealer. By means of an elastic band fasten a cheese cloth screen over the top of the jar. Examine the caterpillars from day to day and report your findings to the class.

4. If the tent caterpillar (Fig. 106) is a common pest in your locality examine in the fall, twigs of trees and bushes around your house. You will find small greyish eggs on the twigs. They are eggs which will hatch into caterpillars. By destroying these eggs you will help to combat the pest.

5. Carefully examine the spider. Count the number of legs on it. Why do you think that a spider is not an insect? Look up and read the life history of a spider. In what way is its history different from that of an insect?

6. Place some moist bread in a dark cupboard or box. Examine the bread a few days later. You will probably find a white mould growing on it. The dark spots on the mould are masses of spores. Examine these with a microscope if your school is provided with one.

PART II

UNIT V

OUR WONDERFUL UNIVERSE

CHAPTER XIII

THE MYSTERY OF THE SEASONS

Can you answer these questions?

1. Would it be possible for one summer to follow another without a winter in between?
2. When it is summer in North America why is it winter in South America?
3. Does the sun really move upwards when it rises?
4. Why is there continuous daylight at the north pole for six months each year?

Life and the Seasons. You will have noticed when you were studying the life cycles of plants that they were adapted, or suited, to the changing seasons. In the spring when moisture is plentiful and the air is warm plants thrive. Spring is the growing season of plants. Leaves and flowers are produced then. During the hot summer the fruits are filled and ripened and food is stored away in the seed and roots. In the cooler autumn the leaves fall and the sap flows to the roots. In the winter, annual plants die, leaving their seeds scattered upon the ground. Plants, animals and human beings alike must adapt themselves to this cycle of the seasons.

You may have wondered why the warm spring is followed by the hot summer and the hot summer in turn by the cool autumn and the cold winter.

Let us examine all the facts we know about the seasons to determine why the changes occur. In winter the weather is cold

and the days are short. As spring advances the weather grows warmer and the days longer. In summer the days are longest and the weather hottest. The autumn weather is cooler and the days shorter. To complete the year we have winter again with its short days and cold.

The fact that the length of the day is so much connected with the seasons suggests that the cause of night and day may be the same as the cause of the seasons.

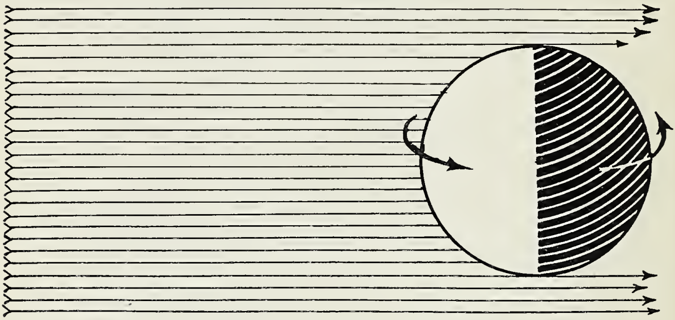


Fig. 116.—Cause of Day and Night

It is daytime when the sun is in the sky and it is night after the sun has set in the west. The sun is the cause of day and of daylight. It appears to rise in the east. During the day it appears to travel high across the sky. At the end of the day it seems to sink below the western horizon.

Ancient Astronomers. The mystery of this daily passage of the sun across the heavens has from earliest times stirred the imaginations of men. Before the age of science men invented strange myths to explain it. Many of the ancient Greeks believed that the sun was carried by a god whom they named Phoebus. Each day he drove a fiery chariot across the sky. At night he dashed back just beneath the northern horizon to his starting point in the east. These Greeks believed the earth to be flat like

a plate, and to have a rim all around the edge. But this explanation did not satisfy all the thinkers of ancient Greece. Some of them gave a more satisfactory explanation. From studying facts they concluded that the earth is spherical or like a ball in shape.[1] The astronomer Ptolemy (A.D. 139-161) made a plan in which he showed the earth as a ball in the centre, with the sun, moon and stars revolving around it daily. He claimed that as the sun moved around the earth it lighted up the side facing it, while the other side remained in shadow. The shadow, he said, made night.

This belief that the earth is spherical[2] led Columbus to sail westward across the Atlantic to reach China. China had before that time always been reached by going eastward. Although Columbus did not reach his goal, other explorers following his lead did reach the Far East, and did sail completely around the world.

Copernicus' Idea. Another idea held by Ptolemy—that the sun revolved around the earth—was doubted by the scientists of who came after him. There were many facts about the stars and planets that this theory could not explain. A Polish astronomer, Copernicus (A.D. 1473-1543) discovered the true answer to the problem. His theory, however, was so different from what men of his time believed that he was afraid to publish it. In those days scientific discoveries were not looked upon with favour.

Day and Night. Copernicus thought that the sun did not move at all. He said that the earth rotated or spun around upon an axis[3] once every twenty-four hours. He said that the rotation of the earth made the sun appear to move across the sky but that it is really the earth which moves (Fig. 116). This explanation is not so

1 Eratosthenes (276 B.C.) a Greek, believed the earth to be spherical. He calculated its circumference to be 25,000 miles.

2 Scientists have since discovered that the earth is not perfectly spherical. Because of its rotation it is bulged at the equator and flattened at the poles.

3 The axis of the earth is an imaginary line through the centre of the earth about which the earth rotates. The northern end of the axis is called the north pole. The southern end is the south pole.

The equator is an imaginary line encircling the globe midway between the north and south poles.

strange as at first glance it may seem. You have seen objects appear to move when they were not moving at all. You may have looked out from a train as it moved from the station. Your first impression was that the station was moving and not the train. So it is with the movement of the earth. The earth moves but the sun seems to move.

This daily rotation of the earth causes day and night. You know, however, that the days and nights are not of the same length throughout the year. They change in length as the year advances. If the earth were merely rotating on its axis the days and nights would always be the same length. There must be some other reason for the seasonal change in the length of the day besides the daily rotation of the earth.

The Seasons. Copernicus supplied the explanation of this. He claimed that the earth revolves[1] around the sun once every year (Fig. 119). Let us examine this idea to see if it will explain why the length of the day changes throughout the year. It will be necessary for you to recall the position of the sun at the different seasons of the year. In the winter the sun appears to rise in the south-east and to travel across the sky not far above the southern horizon and to set in the south-west. As summer approaches the sun seems to rise and set farther and farther north until at midsummer it rises almost directly in the east and sets almost directly in the west after having passed high overhead. As the autumn and winter advance it seems to return once more to its original position in the south.

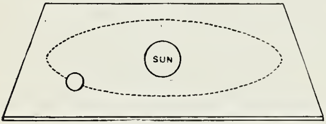


Fig. 117.
The surface of the cardboard represents the plane of the earth's orbit.

The Orbit of the Earth. Let us assume that Copernicus is

[1] When we say the earth rotates on its axis we mean that it is spinning like a top. When we say that it revolves around the sun we mean that the earth moves around the sun just as the weight on the end of a string moves around the hand which swings it.

right and that the earth does revolve around the sun once each year. The path that it follows is called the earth's *orbit.* Let us suppose that an imaginary line joins the earth and the sun. As the earth revolves, this imaginary line will trace an area which is called the *plane* of the earth's orbit. You will understand this better if you draw a small circle in the centre of a piece of cardboard to represent the sun and a large circle around the "sun" to represent the path that the earth follows (that is, its orbit). The cardboard represents the plane of the earth's orbit (Fig. 117).

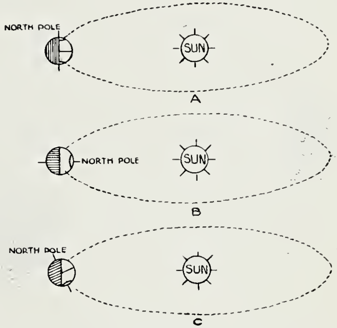


Fig. 118.

If the earth's axis were exactly at right angles to the plane of the earth's orbit, the sun would be directly over the equator (Diagram A, Fig. 118). If you were living in equatorial regions the sun would appear to rise directly in the east and set directly in the west. At high noon it would appear in the zenith[1] directly overhead. At any point in Canada the sun would appear to rise always at the same place and at the same time each morning. It would appear to set at the same place and at the same time each evening. Our experiences tell us that this is not so. We know that the sun appears to rise and set at different times and in different positions as the year progresses.

Now let us imagine that the earth's axis is not at right angles to the plane of its orbit but in line with it so that the north pole points toward the sun (Diagram B, Fig. 118). The northern hemisphere or northern half of the world would in this case have perpetual daylight and the southern hemisphere perpetual night.

[1] The position in the sky directly overhead.

At the north pole the sun would appear to stand still at the zenith and at any other point in the northern hemisphere it would appear to move in a circle in the sky. We know that this does not happen. The earth's axis is neither at right angles to the plane of its orbit nor is it in line with the plane of its orbit. Therefore the earth's axis must lie at an angle between these two extremes (Diagram C, Fig. 118).

Astronomers have calculated that the earth's axis is at an angle of 66½ degrees to the plane of its orbit or 23½ degrees off the

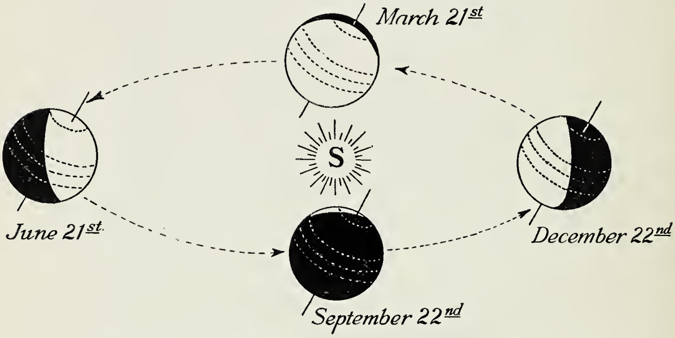


Fig. 119.—The Yearly Revolution of the Earth Around the Sun

perpendicular position. In winter the tilt of the axis causes the north end to point away from the sun and the south end to point toward the sun. This position puts the north pole in shadow. If you were to stay at the north pole you would not see the sun at all during the winter. On the other hand if another person were to stay at the south pole during the same time he would see the sun continuously. It would appear to travel in a circle in the sky.

The Spring and Autumn Equinoxes. You must not forget, however, that the earth is moving constantly in its orbit around the sun once every twelve months. On December 22nd

the north pole is inclined away from the sun more than on any other day of the year. Let us take this position of the earth as the starting point of its yearly journey (Fig. 119). By the 21st day of March the earth will have moved through one quarter of its orbit. The axis will neither point towards the sun nor away from it. The sun will seem to be directly over the equator and it will light up both hemispheres equally. This time of the year is called the Spring Equinox. Three months later, on the 21st day of June, the north end of the axis will be toward the sun. The effect will be opposite to that of December 22nd. Now the south pole is in the shadow and the north in the sunlight. By September 22nd the earth will have covered three-quarters of its orbit and its axis will be in a position similar to that of March 21st. The sun will appear to be over the equator again. This time of year is called the Autumn Equinox. By December the earth will have completed its orbit and winter conditions will prevail in the northern hemisphere.

The Summer and Winter Solstices. As summer approaches we observe the rising of the sun each morning to be a little farther north. On midsummer's day (June 21st) the earth has reached the point on its orbit most distant from its position on December 22nd. From this point as it moves forward in its orbit it begins to approach again towards its December position and sunrise appears farther south each day. The day on which the sun ceases to appear to go farther north is called the Summer Solstice. At this time the sun is over the Tropic of Cancer. If you find this line on the map you will see it is numbered 23½ degrees north. This is the angle the earth's axis is off the perpendicular. In the same way on the 22nd of December, which is called the Winter Solstice, the sun is over the Tropic of Capricorn, 23½ degrees south of the equator.

The Midnight Sun. From the 21st day of March until the 22nd day of September the north pole is in continuous daylight. From the 21st day of March until the 21st day of June there is an

ever-widening circle around the pole within which the sun can be seen for the full 24 hours each day. On the 21st day of June this circle is largest and its circumference is called the Arctic Circle ($66\frac{1}{2}°$ North). From the 21st of June to the 22nd of September the circle gets smaller each day until on the 22nd of September the sun can just be seen at the pole. From the 22nd of September until the 22nd of December there is an ever-widening circle of continuous shadow. Thus for half of the year the north pole is in continuous sunlight and for the other half it is in continuous shadow.

More Daylight in Summer. You now know how the revolution of the earth around the sun makes the sun appear to move northwards during one half of the year and southwards during the other half. How does this yearly movement affect the length of the day? You will understand the cause of the change if you perform this experiment.

Problem

To study the cause of the change in the length of the day.

Plan. If you have a model of the earth and a source of light to represent sunlight you will be able to see for yourself the effect of light on the model.

Apparatus. A black globe (an orange or other spherical object will do). A flash light. Mark the top end of the globe "N" to indicate the north pole.

Method. Darken the room. Place the lighted flash light on a table some distance away. Case 1—Hold the globe so that the axis upon which it rotates is perpendicular to the beam of light. Mark a spot on the globe and rotate the globe at a uniform rate. Case 2—Incline the axis toward the light so that the north pole is toward the light. Again rotate the globe. Case 3—Tilt the axis away from the light and rotate the globe. Repeat the experiment several times, marking a new spot each time.

Observations. Case 1—Are all the spots on the globe in the light the same length of time as they are in the shadow when the globe is rotated uniformly?

Case 2—(a) Are all the spots in light and in shadow the same length of time as the globe is rotated uniformly? (b) Can you find any spots which do not get in the shadow at all? (c) Are there any spots which do not get in the light at all?

Case 3—Is the south pole now lighted as the north pole was in Case 2? Notice carefully spots along the equator. Are they in the light and shadow the same length of time in all cases?

Conclusion. 1. Does the tilting of the globe's axis toward or away from the light have anything to do with the length of time any one spot is in the light and shadow while the globe is rotated uniformly? 2. If the earth's axis were tilted towards the sun would the amount of daylight in the northern hemisphere be determined in the same way?

The experiment you have just done shows you that when the north end of the earth is toward the sun the days are longer in the northern hemisphere than in the southern hemisphere. It also shows that the farther north one goes the longer the days become. If one were to reach the north pole one would be in continuous daylight. Within the Arctic Circle on the day of the Summer Solstice the sun does not set but appears to move in a circle in the sky.

When the earth is tilted so that the south pole is toward the sun the opposite conditions prevail.

From this experiment you will have observed that at the equator the length of day and night is always the same throughout the year. By studying the diagram (Fig. 119) you will see how all the conditions you have set up with the globe occur on the earth as it makes its yearly journey around the sun. The earth's axis is always inclined at 23½ degrees off the perpendicular to the plane of its orbit. In the summer time in Canada the axis is so inclined that the northern hemisphere is in the light longer than in the shadow.

In the autumn on the 22nd of September the north and south poles neither point towards nor away from the sun. Each hemisphere is equally illuminated. The 22nd of September is called the Autumn Equinox because the days and nights all over the world are of equal length. At midwinter, 22nd of December, the south pole is toward the sun. In Canada the nights then are longer than the days. In the spring on the 21st of March the days are again equal to the nights. This day is called the Spring Equinox. You now understand the cause of day and night and why they change in length in the different seasons.

At the beginning of the chapter you set out to discover the cause of the seasons and what relation if any existed between

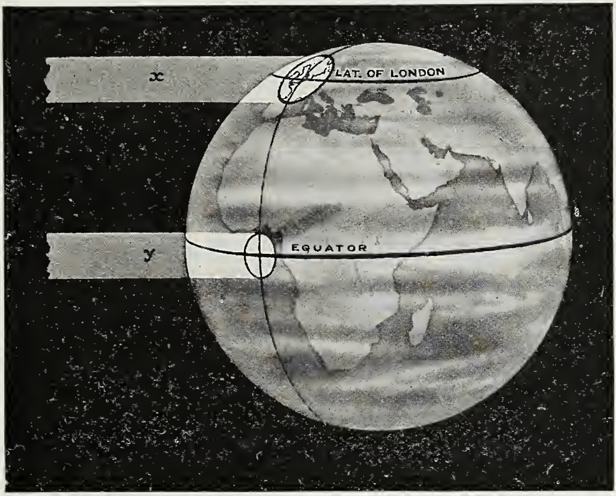
the seasons and the change in the length of day and night. You have gone far toward determining the cause of the seasons. You have found out that the rotation of the earth on its axis is the cause of day and night. You have discovered that the earth's revolution about the sun and the tilting of its axis make the sun appear to move north and then south of the equator as the year passes. You have also discovered that this revolution and this tilting are likewise the causes of the change which occurs in the relative length of night and day as the seasons progress. Have the same facts anything to do with the seasonal changes of temperature with which you are familiar?

Sunlight and Temperature. The temperature of any locality depends upon the amount of heat it receives from the sun. This heat has travelled all the way from the sun. Can you determine how heat travels across space from the sun to the earth? No doubt you have often stood before a camp fire or an open fireplace where the heat was so great that you had to shield yourself from it. A sheet of paper or a towel held in front of you stopped the heat rays and prevented you from being scorched. You have noticed that the heat did not go around the towel. We may conclude that the heat rays[1] travel in straight lines. Therefore the amount of heat which a locality receives will depend upon the number of rays which strike it. This in turn depends largely upon the angle of the surface exposed to the rays. Fig. 120 shows the effect of heat rays from the sun on the earth at the time of the equinox. You can see how the sun's rays spread over a greater area as one travels from the equator towards the poles. The greatest concentration of rays is directly under the sun. The least concentration is where the rays almost miss the earth. The equatorial regions are hottest because the sun's rays are striking perpendicularly, and as one goes north or south the rays strike at a slant because of the

[1] The word ray is related to radiate. Heat and light radiate from the sun in straight lines in all directions just as the spokes of a wheel radiate from the hub. However, because the sun is so far from the earth the rays which reach the earth are practically parallel.

curve of the earth's surface. Towards the poles the curve of the earth's surface is almost in line with the direction in which the sun's rays are travelling.

As the year advances the angle between the earth's surface and the direction of the sun's rays changes. The reason for this is



Drawn By Mr. Scriven Bolton

Fig. 120.

The connection between latitude and quantity of heat received per square mile. Though the beams x and y are equal they spread over different areas of the earth.

the tilt of the earth's axis. Therefore the hottest region moves north or south according to the season of the year.

There are other conditions which affect the temperature of a locality. During the summer the days are longer than the nights. The sun shines longer and this further increases the amount of heat.

You have traced the seasons through their yearly cycle. You know now that the seasons are caused by the revolution of the earth about the sun and by the earth's inclination or tilting at 23½ degrees from the perpendicular. These explanations along with others all show that Copernicus was right when he said the sun does not revolve about the earth but that the earth revolves about the sun.

Guide Words

seasons	rotate	plane of the earth's orbit
spring	stars	equinox
summer	planet	solstice
autumn	perpendicular	Tropic of Cancer
winter	Copernicus	Tropic of Capricorn
horizon	axis	globe
myth	equator	hemisphere
heat rays	Arctic Circle	orbit
astronomer	Ptolemy	illuminated
spherical	sunlight	zenith
revolve		

Signpost Sentences

1. The growing cycle of plants is adapted to the ....
2. In summer the days are long and the sun at noon is near the ....
3. In winter the days are short and the sun at noon is not far above the southern ....
4. .... is the source of all daylight.
5. The axis of the earth's .... is at an angle of 23½ degrees off the perpendicular to the plane of the earth's ....
6. The fact that the earth revolves around the .... and also the fact that the .... of the earth is inclined cause—
   (a) The sun to appear to move north in the summer time;
   (b) the days to become longer than the nights in the summer time;
   (c) the sun's rays to strike more directly and cause the temperature to rise.
7. The date on which the sun ceases its apparent northward movement is called the Summer .... and any place above which it appears to be at noon on that date is on the ....

Questions on Chapter XIII

1. What is the cause of day and night?
2. How did Copernicus explain the sun's apparent movement across the sky each day?
3. What is the earth's orbit? What is meant by the plane of the earth's orbit? What is the inclination of the earth's axis to the plane of its orbit?
4. What is meant by the Summer Solstice?

5. How is the location of the Tropic of Cancer determined by the sun?
6. What is an equinox? On what dates do they occur each year?
7. How did Copernicus explain the sun's apparent movement north and south each year?
8. Explain how the earth's revolution about the sun together with the inclination of the earth affect (*a*) the length of the day; (*b*) the temperature; (*c*) the apparent position of the sun in the sky. Why is the sun visible for twenty-four hours a day within the Arctic Circle at the time of the summer solstice?

Special Problems and Practical Applications

1. From your own observations make notes of ways in which plants adapt themselves to the changing seasons.
2. Why do many birds migrate (or travel) north in the summer and south in the winter?
3. Draw a diagram to show the position of the earth's axis with respect to the sun on the 22nd of December, 21st of March, 21st of June, 22nd of September.
4. Draw a circle to represent the earth and on it mark the equator, Tropic of Cancer, Tropic of Capricorn, Arctic Circle, Antarctic Circle. Make notes underneath of the position of the sun with respect to these lines on the dates given in question 3.

CHAPTER XIV

THE SUN AND THE MOON

Can you answer these questions?

1. Why cannot the stars be seen during the day?
2. Would life on the earth be possible if there were no sun?
3. Is the moon as large as the sun?
4. Why does the sun or the moon not fall on the earth?
5. What is gravity?
6. What causes an eclipse of the sun? an eclipse of the moon?

The Importance of the Sun to Mankind. You have welcomed the relief of a cool night after a hot day. If the earth did not rotate there would be no such relief. The heat from the sun's rays would make the land hotter than an oven. Living things could not exist because of the heat. On the other hand the dark side, or night side, of the earth would offer no relief. The cold there would be greater than any cold you have ever known, colder even than the north pole. The oceans on the dark side would be solid ice. These extremes of heat and cold do not occur because of the rotation of the earth: the bright side of the earth moves into the shadow and cools before the sun has made it unbearably hot; the dark side moves into the sunlight before it has lost all of its heat.

For ages men have recognized the sun as the source of the earth's heat. They knew that without the sun life would be impossible. Many ancient peoples worshipped the sun. The chief god of the Egyptians was Ra, the sun god. Mithras was the sun god of the Persians. The natives of Mexico and Peru built beautiful temples in which to worship the sun. The people of the modern world also know its importance to them. But

educated people do not now worship the sun as a god for scientists have revealed to them the real nature of the sun.

The Sun. Scientists have proved that the sun is a sphere like the earth and that the earth revolves or travels around it. Astronomers have calculated the diameter of the sun to be about 866,000 miles. The earth's diameter is 7,918 miles. You will see that the sun's diameter is more than 100 times as great as that

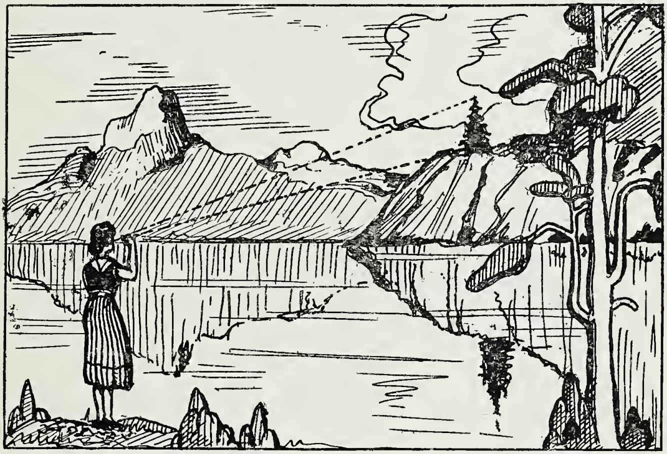


Fig. 121.
A coin held in the hand will completely hide a tree on a distant hillside.

of the earth. The distance around the equator of the sun is about 2,500,000 miles. In volume it is about 1,300,000 times greater than the earth.

Since the sun is so large why does it appear so small in the sky?

The farther an object is away from you, the smaller it appears. A coin held at arm's length will hide a tree upon a distant hillside (Fig. 121), but if the coin were as distant as the tree it

would not be seen at all. Because the sun is more than 1,300,000 times as large as the earth it must be a long way off to appear so small. It is, in fact, about 93,000,000 miles from the earth. It is difficult to realize how great this distance really is. If you were riding in an aeroplane which travelled at 100 miles an hour it would take only 10½ days to travel around the earth's equator. At the same speed it would take 105 years to travel the distance the sun is from the earth.

Measuring Distance in the Sky. How have scientists been able to measure this great distance? It is measured by a system of *triangulation* in which triangles are used. You can work a simple problem in triangulation in order that you may understand how astronomers use triangulation in measuring distances.

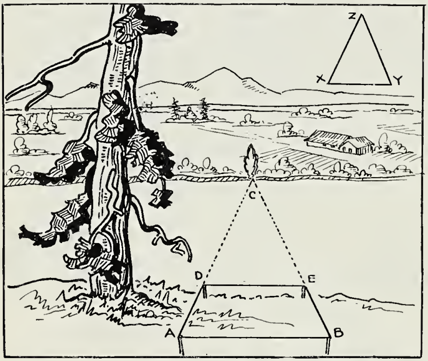


Fig. 122.—How to Calculate the Width of a River by Triangulation

PROBLEM

To calculate the distance across a river by the method of triangulation.

Plan. To do so by using triangles as shown in the diagram (Fig. 122). If a large triangle A B C could be laid across the river so that its base would lie along the bank then the base and the angles at its ends could be measured. By using angles of the same size as the measured angles a new triangle X Y Z the same shape as the first could be drawn on a piece of paper. Suppose the base of the triangle X Y Z were one hundreth the length of the base of the triangle A B C. Then the other sides of X Y Z would be one hundreth of the other sides of A B C and the distance across the river could be found.

Apparatus. Four sharpened stakes, a ball of twine, four nails, a tape measure, a piece of drawing paper.

Method. Drive the stake A in the ground and drive a nail in the top of it. Measure 25 feet along the bank and drive the stake B. Drive a nail in the top of B so that it is exactly twenty-five feet from the nail

in A. Stretch a string tightly between the two nails. This is the base of your triangle. At D drive another stake so that it is exactly in line with a tree C on the opposite bank and with A. Drive another stake at E so that B, E and C are all in line. Drive nails in the tops of D and E. Stretch a string from the nail in D to the nail in A and also a string from the nail in E to the nail in B. By holding the piece of drawing paper under the strings at A and at B carefully trace the angles C A B and C B A. On another piece of paper draw a straight line exactly three inches long. Mark one end X and the other Y. At X make an angle equal to the angle C A B and at Y make one equal to angle C. B A. Complete the triangle by extending the lines until they meet at Z.

Observation. The triangle X Y Z is of the same shape as the triangle A B C.

Conclusion. Since the base X Y is three inches, or one-fourth of a foot. Therefore, the base A B is one hundred times longer than X Y. Consequently B C will be one hundred times longer than Y Z and A C one hundred times longer than X Z.

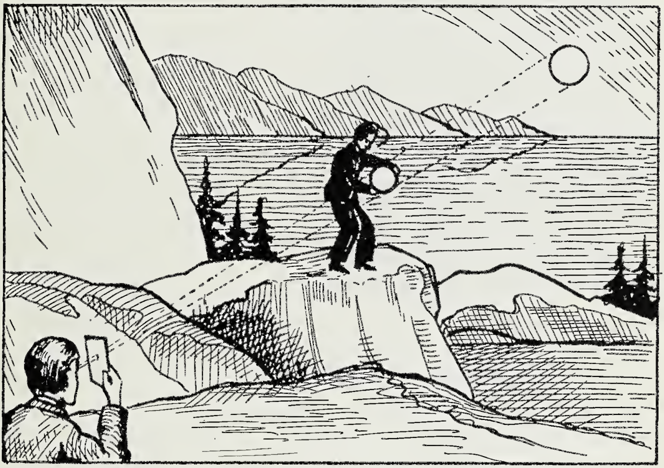


Fig. 123.—Calculating the Size of the Sun.

Surveyors use the method of triangulation for mapping land and calculating distances. They have very accurate instruments for measuring base lines and for finding angles. They do not have to draw each triangle on paper as you did. A system of mathe-

matics called trigonometry or angle measurements has been worked out to help them solve their problems. It is found that this method of measuring great distances is more accurate than actually measuring with a measuring tape.

Astronomers use methods similar to those of surveyors. They also use triangles to measure the distances between stars and other heavenly bodies. Since the distance to the sun is so great, they must take great pains to measure their angles accurately. The distance to the sun as calculated by triangulation is about 93,000,000 miles. When the distance to the sun is known, then by triangulation astronomers can also calculate its size.

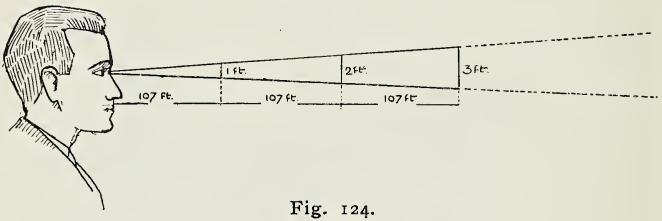


Fig. 124.

The Size of the Sun. You will recall that a penny held at arm's length will completely hide a distant tree. A dinner plate one foot in diameter held at arm's length will hide the sun. It will hide a great deal of the sky as well. Have a friend carry the plate towards the sun until the plate just covers the sun as seen from where you stand (Fig. 123). Measure the distance from where you stand to the plate. You will find it is about one hundred and seven feet. It will be plain if you refer to the diagram (Fig. 124) that a plate would have to be two feet in diameter to cover the sun if the plate were twice as far from you. A plate three times as far from you would have to be three feet in diameter. Then it is clear that the sun is as much larger than the plate in diameter as 93,000,000 miles is greater than one hundred and seven feet. If you are good at arithmetic you can work this problem for yourself.

Composition of the Sun. It is injurious to the eyes to look directly at the sun unless you do so through a dark glass or some substance which will soften the glare. The sun's light is so bright that it dazzles the eyes. What is the source of the light? Of what is the sun composed? The secret of the composition of the sun would still be hidden were it not for an instrument called the spectroscope. The spectroscope analyses the sunlight. It reveals the fact that the surface of the sun contains the same kind of materials as our earth. The materials on the sun, however, are not solid. The sun is so hot that everything on its surface is melted. It is estimated that the temperature of the sun at its surface is about 10,000 degrees Fahrenheit. The very hottest flames made on the earth are not so hot as the surface of the sun. It is, therefore, easy to understand why the sun gives off so much heat.

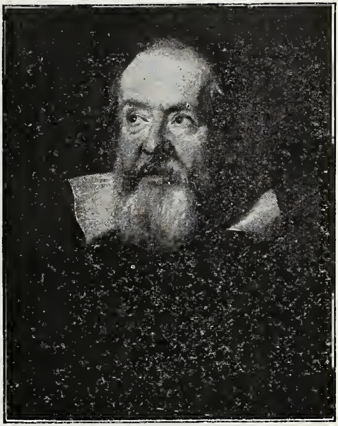


Fig. 125.—Galileo

The first scientist to study the sun with a telescope. He discovered sunspots.

Sunspots. Scientists are still studying the sun and learning more about it. Before the telescope was invented it was thought that the sun had no markings on its surface. Through his telescope Galileo (Fig. 125) saw that dark markings appeared upon the sun from time to time. He called them sunspots (Fig. 126). The exact nature of the sunspots is not known but under certain conditions great flames of gaseous material can be seen streaming from them. These flames are called *solar prominences*. It is thought that they are caused by explosive eruptions of the white-hot

material inside the sun. As the flames shoot upward they become cooler and darker.

Sunspots are more numerous at some times than at others. When the sunspots are numerous the earth experiences magnetic storms; the compass needle is turned from its true direction; radio and telegraphic communication is interfered with; great displays of northern lights, or the aurora borealis, are seen. By

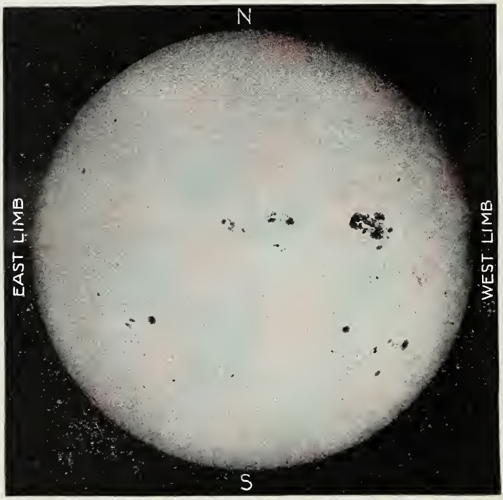


Fig. 126.—Photograph of the Sun, Showing Sunspots

serving sunspots astronomers have been able to show that the sun rotates. They have calculated that at its equator it takes the sun twenty-five days to rotate once upon its axis.

The Moon. After having studied the sun, you will wish to learn about the moon. Although the full moon appears to be as large as the sun there are many differences between them. You

have observed the monthly changes in the appearance of the moon. At one time it is a thin curved band called the crescent moon (Fig. 128). This gradually waxes or grows until the half-moon is formed. The half-moon waxes to the full-moon. If you are a close observer and watch every night you will see the full-moon wane or fade away to the half-moon and finally to a crescent.

Drawn by Mr. Scriven Bolton

Fig. 127.—A Sunspot

This cycle of change in the appearance or phases of the moon is completed in about four weeks. It is repeated about thirteen times a year. People of early times used these regular changes

of the moon as a calendar or measure of time. Each cycle was called a month. Month is a shortened form of "moonth".

Comparing the Moon With the Sun. Not only is the moon different from the sun in its phases but also in the appearance of its surface. While to the unaided eye the disc of the sun seems clear, there are decided markings upon the moon.

Another difference between the sun and the moon is in the amount of light the earth receives from them. Although the full-moon seems to light up the whole earth, the actual amount of light received from it is about one five-thousandth of that

Courtesy Yerkes Observatory

Fig. 128.

These photographs show four phases of the waning moon. Can you locate the peculiar ringed mountains or craters on the surface of the moon?

received from the sun. The light of the moon is really sunlight which has been reflected. The moon has no light of its own.

If, for a month, you were each evening to note the time when the moon rises you would find that the rising of the moon is not so regular as the rising of the sun. You would find that on some occasions the moon rises even in the daytime.

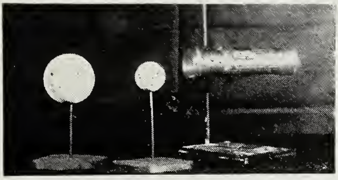
Phases of the Moon. You will understand the peculiar appearances and movements of the moon if you think of the moon as being a sphere or ball which is closer to the earth than to the sun. You should do an experiment to see how this is so.

PROBLEM

To find the cause of the moon's phases (Fig. 129).

Plan. If you use a source of light to represent the sun; and a ball to represent the moon you should be able to show how moving the ball will alter the appearance of the light and shadow on it.

Apparatus and Materials. A flashlight, a golf ball suspended by a string or held on a needle.



A

The flashlight represents the Sun, the golf ball the Moon, and the large ball the Earth. The "moon" is to be moved around the "earth" during this experiment.

B

Can you find the direction of the source of light? Can you locate the position of the observer? What phase of the moon is represented? Why does not the whole of the "earth" appear to be lighted up?

C

What change has taken place in the position of the "moon"? What change, if any, has taken place in the position of the observer?

D

What phase is the "moon" approaching? Where is the "sun" in relation to the observer?

Fig. 129.—An Experiment to Illustrate the Phases of the Moon

Would an observer on the moon see phases of the earth as we see phases of the moon?

Method. Have a friend stand at one end of a darkened room with a lighted flashlight. This will represent the sun. You can take a position in the centre of the room to represent the earth. Have a second friend hold the suspended golf ball which represents the moon, so that the light shines upon it.

Observation. 1. When the golf ball, representing the moon, is between you and the "sun" what phase of the real moon does it resemble? 2. When the "moon" moves around you what changes in its appearance take place?

3. When it has gone one quarter of the way around what phase of the real moon does it resemble? 4. When it has gone half way so that it is on the opposite side of you to the sun, what phase do you see?

Conclusion. If the moon were a sphere revolving around the earth would the sunlight reflected from it cause changes in its appearance like the changes you saw in the appearance of the golf ball?

The experiment shows you that the changes in the appearance of the moon or the moon's phases are caused by the movement of the moon around the earth. (The moon is a *satellite* or follower of the earth.) It also shows you that the moon does not shine by its own light but that it shines by reflected sunlight. This explains why moonlight is not so bright as sunlight. Moonlight is reflected sunlight.

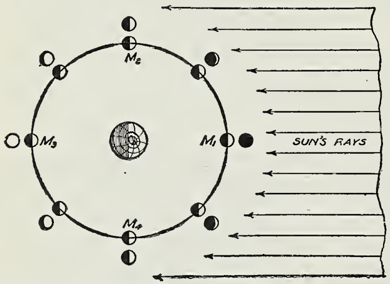


Fig. 130.—The Causes of the Phases of the Moon

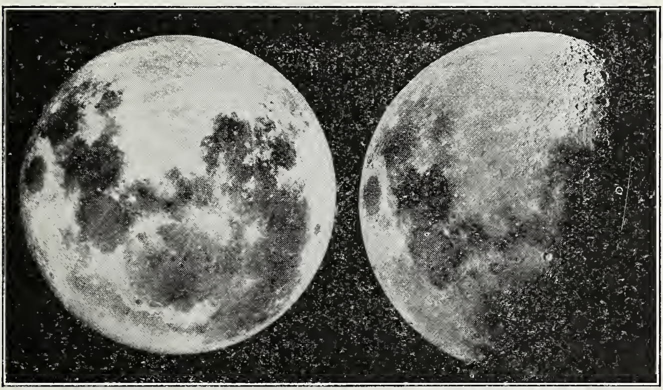
The moon passes through all its phases as it makes one revolution around the earth.

Because the moon is much closer to the earth than the sun you can see its surface more clearly. If you look at it through a telescope it is seen to be a sphere. It is covered with high mountain ranges and deep valleys. Astronomers have been able to calculate its size and its distance from the earth. The diameter of the moon is 2,163 miles and its average distance from the earth is 240,000 miles. Compared with the sun the moon is very close to the earth and very small. The moon appears to us to be as large as the sun because it is so much nearer.

The moon revolves around the earth, making a complete revolution in twenty-nine and one-half days. This length of time is called a lunar month. You must not forget that the earth rotates upon its axis once in twenty-four hours. This rotation makes the

moon appear to revolve around the earth every day just as the sun appears to do. The time of the apparent revolution of the moon seems to be a little longer than twenty-four hours for the reason that the moon is revolving around the earth in the same direction that the earth is rotating. This is why the moon seems to rise a little later each night.

Why the Moon Does Not Fall. You may wonder why the moon does not fall to the earth for it is a ball of solid rock.



Courtesy Yerkes Observatory

Fig. 131.—(Left) the Full Moon, (Right) the Moon at 9¾ Days

You know that things which are not held in place all fall to the earth. Why does the moon not share the same fate? Is it possible that the gravitational force of the earth does not reach as far up as the moon? Sir Isaac Newton, a great English scientist, demonstrated that the earth's gravitational force (that is the force which pulls things to the earth) does reach to the moon. What, then, keeps the moon from falling? Perhaps you know the answer. Did you ever fill a pail with water and swing the pail around in a circle? You will have noticed that the water does not spill out even though at times the pail is upside down.

The force which holds the water in the pail is the same force which caused mud to fly off a spinning bicycle-wheel. This force which pushes away from the central point is called *centrifugal* force. The moon is whirling or revolving around the earth. It then has a tendency to fly away from the earth like the mud from a wheel. The gravity of the earth, however, prevents this. The centrifugal force is just equal to the gravitational force and so the moon stays in its course.

Tides; Caused by the Moon and Sun. The moon is a world like the earth. It has its own force of gravity and attracts objects

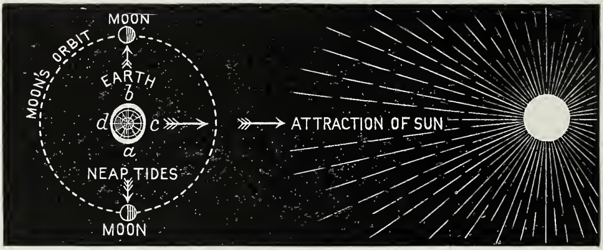


Fig. 132.—The Formation of Neap Tides
They occur when the gravitational pull of the moon acts in a direction at right angles to that of the sun.

towards itself. Objects near the moon fall upon it. The moon attracts the earth in the same manner that the earth attracts the moon. You can see the effects of this attraction if you visit the ocean shore where the tides rise and fall. Whenever the moon is above the ocean the level of the water beneath it is raised by the gravity of the moon. Because the water is fluid it is attracted toward the moon by this gravity and so forms a large bulge on the ocean. As the earth rotates this bulge of water moves along the surface of the ocean. This bulging of the ocean water is called the tide. High tide is caused as the bulge approaches the shore and low tide when it moves away. This explains why there are daily tides (Figs. 132 and 133).

High tide occurs at opposite sides of the earth at the same time because the earth is pulled away from the water on the opposite side just as the water is pulled away from the earth on the side near the moon. That is why there are two high tides and two low tides each day. When the tide is rising it is called flood tide; when it is falling it is called ebb tide.

The sun also has gravity. The gravity of the sun has an effect on the tides but this effect is very small because the sun is so far away. Whenever the moon is "full" or whenever it is "new", the gravity of the sun is pulling in the same direction as the gravity of the moon as far as the earth is concerned. This

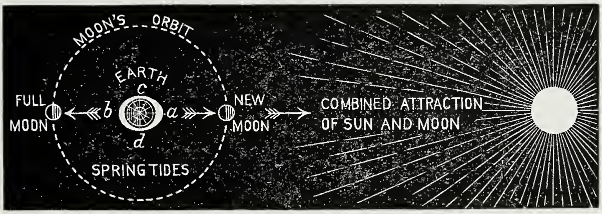


Fig. 133.—The Formation of Spring Tides
They are due to the combined gravitational pull of the moon and sun.

causes the tides to be higher than usual. These very high tides are called *spring* tides. When the moon is either in the first quarter or in the last quarter the gravitational pull of the sun upon the earth is at right angles to that of the moon. Hence the tides are lower than usual. These low tides are called *neap* tides.

Eclipses. As the moon revolves around the earth, the earth is revolving around the sun and takes the moon along with it. Sometimes all three are in one straight line. If the earth is between the sun and the moon, when this happens, it will cast a shadow upon the moon. The earth's shadow completely covers the moon. This is called a *lunar eclipse* or an eclipse of the moon. If you watch a lunar eclipse (Fig. 134B) you will see the circular shadow of the earth creeping across the face of the moon.

When the moon is between the sun and the earth and all three are in one straight line, the moon casts a shadow upon the surface of the earth. Because the moon is so much smaller than the earth its shadow does not cover the earth. In fact the shadow of the moon upon the earth is very much smaller than the moon. Can you, by studying the diagram, tell why this is so? Compare the shadow cast by the moon with the shadow cast by a small object near a window. Inside the area covered by the shadow of the moon the sun is completely hidden from view. It is said to be in total eclipse (Fig. 134A). At such a time the stars can be seen plainly and night seems to fall for a few minutes. At that time, too, the solar prominences or the huge flames which shoot out from the surface of the sun are easily seen. The peculiar crown of light which is called the corona of the sun also becomes visible (Fig. 135).

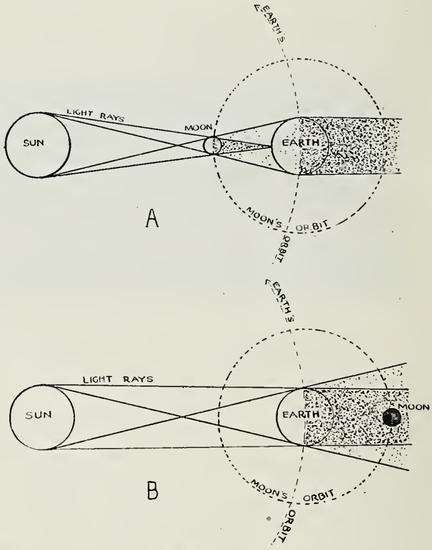
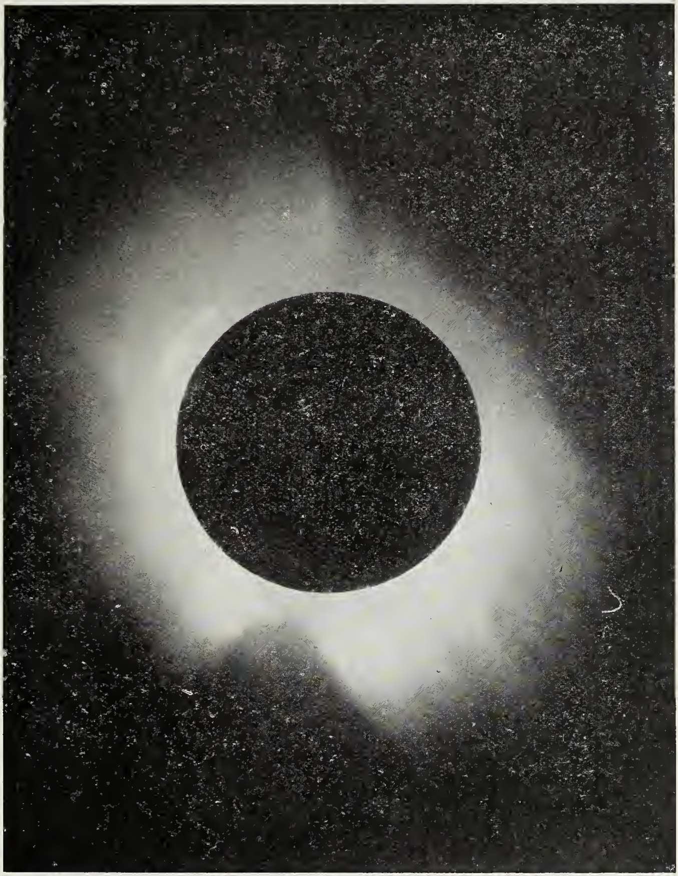


Fig. 134.—How Eclipses of the Sun and of the Moon Occur

Neither the prominences nor the corona can be seen in ordinary daylight. Later, you will learn the reason for this. As the earth rotates the shadow of the moon moves along its surface. The path it follows is called the *path of totality*. Such an eclipse travelled across the province of Quebec on August 31, 1932. It



Courtesy A. C. Crommelin, Greenwich Observatory

Fig. 135.—The Sun's Corona

The corona can be observed only during a total eclipse of the sun.

was observed by astronomers who had journeyed from all parts of the world. It is one of the great achievements of scientists that they are able to predict years in advance the exact time when an eclipse of the sun will occur and to plot the path of totality long before the eclipse occurs.

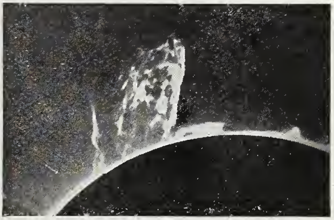
An Imaginary Journey. Let us in imagination now travel to the moon. We shall have to prepare for this imaginary voyage as it will be a long one. The moon is 240,000 miles away. We shall have to carry food with us. We shall have to carry a supply of air also, for the earth's atmosphere does not extend to the moon. Our ship then will have to be airtight and must be provided with tanks of oxygen. We shall have to provide chemicals to absorb the carbon dioxide which we shall breathe out. The journey will be a cold one. The temperature of outer space has been calculated to be about 400 degrees Fahrenheit below zero. Our ship will have to be built to hold heat as a vacuum bottle does. We shall need electric heaters to keep us warm. Because there is no air in outer space propellors will be useless for driving the ship. For driving power we shall probably use rockets or explosions. The recoil or "kick-back" of the explosion will drive the ship forward. Such a trip, you will see, presents many difficulties, but let us imagine that we have overcome them all and that we are ready to take off.

Let us bid good-bye to the earth and be off. The doors must be bolted tightly. We must brace ourselves firmly for the starting shock. We're off! We are going to travel quite fast. Our ship is built to travel 1,000 miles an hour. Even at this speed it will take many days to reach the moon.

As we leave the earth we shall see some interesting changes. At first it appears to be a saucer-shaped plain beneath us. As we rise we see more and more of its surface. Distant towns come into view. Gradually the saucer-shaped plain seems to flatten out and then to form into a huge ball. The ball grows smaller each day as we travel away from it. The continents are seen very much as they are on the classroom globe. We do not

have much time to look at the earth, however, as there are so many other interesting things to see.

We examine the sun through another window. How different it appears now that we have left the earth's atmosphere behind us. We can see quite plainly the corona and the prominences which can be seen on earth only during an eclipse (Figs. 135, 136). How much more brilliant the sun seems now, though strangely enough we seem to be travelling at night. The stars are all visible and there is darkness about us, because there is no atmosphere to diffuse or scatter the light of the sun. On earth the stars cannot be seen during the day because the sunlight causes the atmosphere to glow more brightly than the stars.



Courtesy J. Evershed, Kodaikanal

Fig. 136.—Solar Prominences

Photographed during a total eclipse of the sun.

There seems to be something wrong. We are not heading towards the moon. The captain explains that if we kept the ship heading towards the moon it would take much longer to get there. He says that as the moon is revolving around the earth we shall meet it by travelling at an angle ahead of it and so we shall save time. The captain also says that soon we shall have to stop the explosions which propel us away from the earth as we shall be past the point where the gravitational pull of the moon is equal to the gravitational pull of the earth. We shall then be falling towards the moon. However, the explosion-tubes in the forward part of the ship will be started to check the downward fall and to prevent us from crashing upon the moon.

As we approach the moon we are struck by the difference of its appearance from that of the earth. Because the moon has no atmosphere everything is seen more clearly. The mountain ranges are different. Many of them appear to be large craters

of volcanoes. They are higher and more rugged than the mountains of the earth. Their jagged peaks seem to be about three

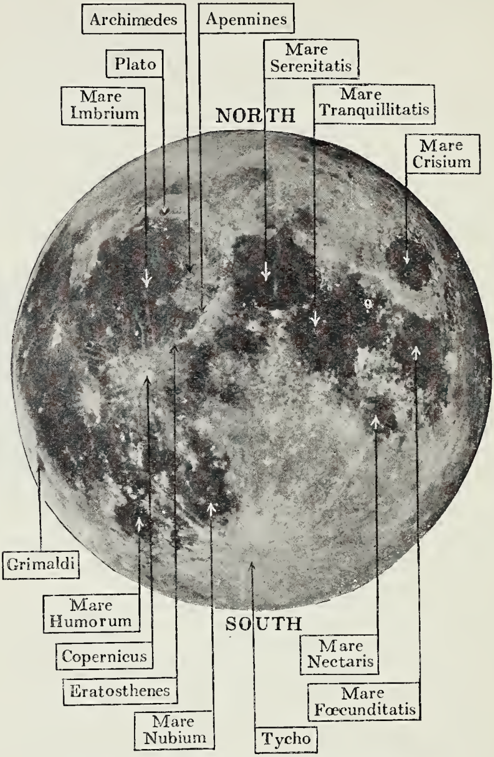


Fig. 137.—Photograph of the Moon
The mountains and "seas" have been given names by the astronomers. *Mare* is the Latin word for sea.

times as high as the mountains we have known. They are rocky and sharp because there is no air or water to cause erosion.

The captain is pointing out to us the different ranges. He says they can be seen quite plainly from the earth with a powerful telescope and that astronomers have named nearly all of them. The dark patches upon the moon are called seas but they do not contain any water. We always see the same side of the moon because it rotates on its axis in exactly the same length of time that it revolves around the earth.

The captain tells us that if we could land we should find our weight to be about one-sixth as much as it is on earth because the *gravity* of the moon is only one-sixth as much as the *gravity* of the earth. If a boy could jump five feet on earth he could jump thirty feet upon the moon with the same amount of effort. He would be able to clear an average house with one leap. However we cannot land for the purpose of testing our jumping ability. The captain says the surface of the moon would be far too hot for comfort. He reminded us that instead of twelve hours of sunlight the surface of the moon is lit up for about fifteen days at one time. The captain also points out that there is no atmosphere on the moon and that the gravity of the moon is not great enough to hold an atmosphere. As a result of this he says there is no sound on the moon because sound travels in air.

Returning from the neighbourhood of the moon, we seem to go upwards in order to reach the earth. The earth now appears to be high above our heads, just like a moon. It appears to have four times the diameter of the moon at which we are accustomed to look from the earth. It does not, however, have the same brilliance. A glowing halo of light encircles it. This is its atmosphere made luminous by the sunlight. If we were to stay long enough near the moon we should see phases of the earth just as on earth we see phases of the moon. We shall be unable to stay as our supplies are running low, besides we shall be glad to get back to earth once more for a breath of real air and a chance to stretch our legs. The cramped quarters of our ship

have become wearisome and we long for the green fields and cool waters of the earth.

Guide Words

triangulation	spectroscope	Galileo
sunspots	telescope	path of totality
northern lights	eruptions	full-moon
crescent	magnetic storms	wanes
prominence	waxes	gravity
centrifugal force	phases	eclipses
corona	tides	vapours
atmosphere	rotation	reflects
diameter	volume	orbit
revolves	sphere	circumference

Signpost Sentences

1. The earth's .... prevents extreme heat or extreme cold.

2. The sun's .... is about one hundred times greater than that of the earth. Its .... is one million three hundred thousand times greater than that of the earth.

3. The sun's surface is composed of white hot .... The .... shows that the vapours of the sun contain the same materials as are found on earth.

4. The earth's .... is about 93,000,000 miles away from the sun.

5. Astronomical distances can be calculated by ....

6. The moon .... around the earth and it accompanies the earth as the latter .... around the sun.

7. The moon shines because it .... the sunlight.

8. The .... of the moon are caused by the changing amount of sunlight we see reflected as the moon revolves about the earth.

9. .... is the force with which bodies attract each other. Its cause is unknown. .... gives bodies which are whirling in a circular path a tendency to fly away from the central point about which they are whirling.

10. The moon keeps in its course because the force of gravity and the ....acting on it are equal.

11. The moon is a .... 2163 miles in diameter. It is 240,000 miles away from the earth.

12. The moon has neither .... nor water.

13. .... are caused when the sun, the moon and the earth move into the same straight line.

Questions on Chapter XIV

1. What prevents the earth from becoming extremely hot or extremely cold?

2. Although the sun is so much larger than the moon why does it seem to be the same in size when seen from the earth?

3. How can astronomers calculate distances in space?
4. How do scientists determine that the surface of the sun contains the same kinds of materials that we have on earth?
5. How do astronomers know that the sun rotates on its axis?
6. What are the phases of the moon? What causes them?
7. How could you demonstrate the movement of the moon around the earth?
8. Why does the moon appear to rise later each day?
9. How does the gravitational force of the moon affect the earth?
10. Why are some tides higher than others?
11. How is an eclipse of the sun caused?
12. How is an eclipse of the moon caused?

Special Problems and Practical Applications

1. How could you measure the height of a mountain without climbing it?
2. Knowing that the moon is 240,000 miles away how could you calculate its diameter?
3. Why is it possible to publish an accurate tide chart for a year in advance?
4. What conditions on the moon would prevent human beings from living there?
5. If the earth were represented by a circle one inch in diameter, what would be the diameter of the circle you would have to draw to represent the sun in the same proportion?
6. How could you demonstrate centrifugal force?
7. Astronomers are able to aid navigators through the preparation of tide charts. Of what value is this to navigators?
8. Many superstitions have arisen concerning the influence of the moon on the lives of people. Can you find any reasons for believing or disbelieving such stories?

Home Projects

1. Secure two lenses such as magnifying glasses, one large and one small. Mount them in two cardboard tubes so that one tube will slide inside the other. By experimenting you can determine the proper length of tubes to suit your lenses. You will then have a simple telescope.
2. (*a*) From your own observations determine how long it is in time from one new moon to the next.
   (*b*) Determine how much later the moon rises each day during the month.

CHAPTER XV

THE STARS

Can you answer these questions?

1. Are the same stars always to be found in the heavens?
2. Are there any "lucky" or "unlucky" stars?
3. Do stars ever fall?
4. What becomes of the stars in the daytime?
5. Which is the larger, the moon or a star?
6. Are planets and stars the same?
7. What is the "Milky Way"?
8. Is Mars inhabited?
9. Do comets bring disaster to the earth when they appear in the sky?
10. How far does light travel in one second?
11. Is the earth the largest planet?
12. Why does Halley's comet return to the sky every seventy-six years?
13. How far away is the nearest star?

Mapping the Stars. As the twilight deepens you have noticed the bright stars making their appearance one by one until the whole sky becomes a canopy of twinkling lights.

If you study the stars you will learn that the same groups of stars are to be found each night and you will soon look forward to seeing these familiar groups as if they were old friends. Will they always be the same? Will you be able to see the same familiar stars ten, twenty, or thirty years from now?

The stars have been grouped as we see them for thousands of years. They have remained nearly in the same position with respect to one another as long as man can remember. The same

stars that are seen tonight were twinkling when the pyramids were being built in Egypt five thousand years ago.

We know that these stars are the same because very early people made maps or charts of the heavens, and we see in these charts the stars we see today (Fig. 138).

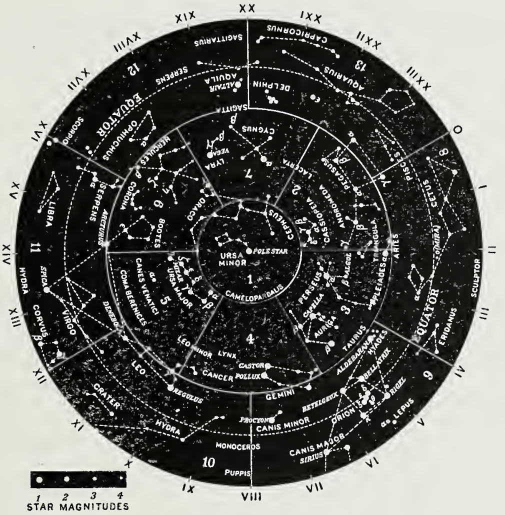


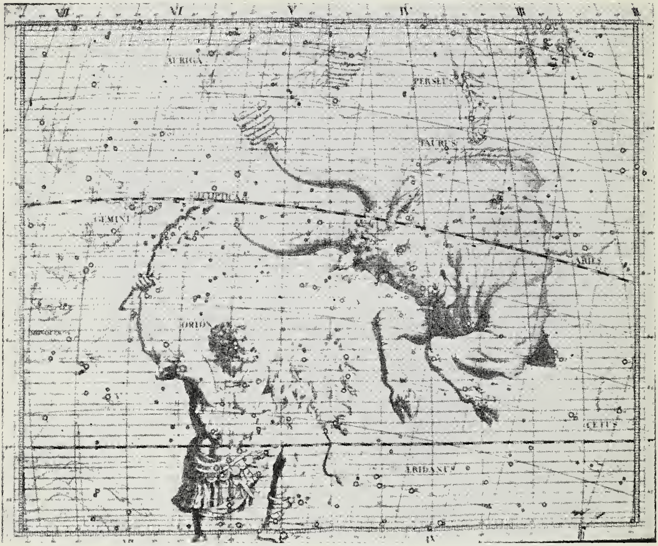
Fig. 138.

Can you locate Ursa Major (the Big Dipper, sometimes called the Plough) in this group of stars? Two of the stars in the Big Dipper are called pointers because they are in line with the Pole Star.

How the Stars Were Named. These early people gave fanciful names to the star groups or *constellations* (Fig. 139). They named the constellations after the people and animals of their popular myths. They imagined that they could see the figures of their heroes outlined among the stars. Astronomers still use these names to distinguish the constellations. These names will

be used for many years to come because these same constellations, with but little change, will still be found in the heavens for ages.

You will notice that the stars appear to move each night. The apparent movement of both the sun and the stars is due to the rotation of the earth.



From Flamsteed's Atlas

Fig. 139.—Orion and the Neighbouring Constellations

The stars really remain "fixed" in space. Their position with respect to one another has changed but slightly during the last two thousand years. For this reason they are called fixed stars.

The Wandering Planets. Not all the stars are "fixed". Even in the earliest times astronomers had noted that certain stars appeared to wander among the fixed stars. They named them *planets* or wanderers. They were different from the fixed stars

in yet another way: they shone with a steady light and did not twinkle as the fixed stars do. Their peculiar movements among the stars were very difficult to account for until the astronomer Copernicus explained that they were worlds, which, like our own, revolved in orbits around the sun. It was hard to believe at first that these tiny points of light were great worlds but when the planets were examined through telescopes this was found to be true.

Our own earth is a planet. From the earth eight other planets can be seen. Not all of them can be detected with the unaided eye. Some of these eight planets are so distant that they can be seen only with the aid of a telescope.

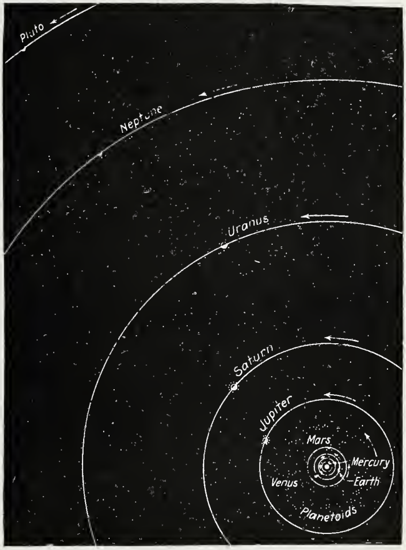
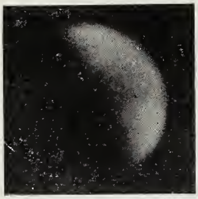


Fig. 140.
Planets move in orbits around the sun.

Mercury. Some of the planets revolve around the sun in orbits (Fig. 140) which are much closer to the sun than the earth's orbit. Mercury is the planet nearest to the sun and because it is so close to the sun, it is very difficult to observe. It revolves around the sun in one quarter of the time that the earth does. It completes one revolution around the sun in eighty-eight days or in just three of our months. Imagine a year only three months long!

Because of its speed this planet was named after Mercury,

the swift wing-footed messenger of the gods. Its orbit is not quite circular but is elliptical. As it travels on its orbit the average distance of Mercury from the sun is about 36,000,000 miles. It has a diameter of 3,009 miles, so that Mercury is just a little larger than our moon and like the moon it is too small to hold an atmosphere. It is thought that Mercury rotates on its axis once in eighty-eight days or in the same time that it takes to revolve around the sun. This means that one side of Mercury faces the sun always and must be a desert of scorching heat. The opposite side must be a frozen waste.



Courtesy W. H. Wright, Lick Observatory

Fig. 141.—An Actual Photograph of Venus

Venus. The second planet from the sun is Venus, one of the brightest of the planets, named after Venus, the Roman goddess of beauty. It is 67,200,000 miles from the sun. At certain times of the year, Venus is the brilliant evening star. At other times it is the morning star, which rises just before dawn.

Venus (Fig. 141) is only slightly smaller than our earth; it has a diameter of 7,701 miles. It revolves around the sun once in 225 days or in about seven and one-half of our months. Astronomers differ as to the time it takes to rotate on its axis. Some say it rotates in 23½ hours. Other astronomers claim that its period of rotation is much longer. Venus, like our earth, possesses a cloudy atmosphere. It is this which prevents its surface from being seen and its period of rotation from being accurately determined. If the period of rotation were about twenty-four hours life on Venus would be possible just as it is on the earth. Venus is sometimes called the earth's twin sister. It is much warmer on that planet, however, because Venus is much closer to the sun.

Earth. The third planet from the sun is our own earth. As you have learned its period of revolution around the sun is 365¼ days. It is about 93,000,000 miles distant from the sun and it rotates on its axis so that from noon on one day to noon the next

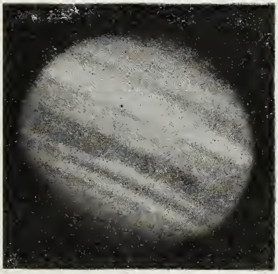
takes just twenty-four hours. We call this period one solar day.[1]

Mars. The fourth planet from the sun is the red planet, named Mars (Fig. 142) after the Roman god of war. This planet has a diameter of 4,339 miles, or about half that of the earth. It is 141,500,000 miles from the sun. It has two small moons revolving around it. Mars revolves around the sun once in twenty-three of our months. Its year, therefore, is almost twice as long as ours. Its period of rotation on its axis is twenty-four hours and thirty-seven minutes. The atmosphere of Mars is very light so that surface markings on Mars can be detected with the aid of a telescope.

Courtesy W. H. Wright, Lick Observatory

Fig. 142.—An Actual Photograph of Mars

Some astronomers have observed lines on its surface. These lines they have called canals. As the seasons in Mars advance the changes in colour along the canals suggest the growth of plant life. This has led to the belief that these canals may have been dug by intelligent beings, perhaps like ourselves. But as Mars is 141,500,000 miles from the sun it receives from it much less heat than the earth, and life for beings like ourselves would be difficult on Mars.



Courtesy W. H. Wright, Lick Observatory

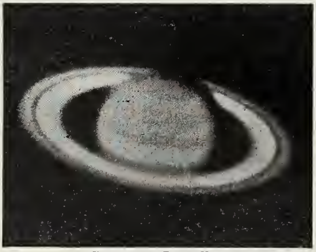
Fig. 143.—An Actual Photograph of Jupiter

Note the dark bands and the bulging at the equator caused by the rapid rotation of the planet.

[1] The actual time of the earth's rotation is 23 hours and 56 minutes. This is called a siderial day. But because of the earth's revolution around the sun, its apparent rotation, that is from noon to noon, is 24 hours. This is the solar day.

There is room for a great deal of argument for and against the possibility of life upon Mars.

Jupiter. The fifth planet is Jupiter (Fig. 143), the largest of the planets. Its volume is more than a thousand times that of the earth. Its diameter is about 88,000 miles. Its period of rotation upon its axis is nine hours and fifty minutes. As a result of its great size and rapid rotation Jupiter is flattened at its poles and bulged along its equator. It has nine moons revolving around it. Four of these are about the size of our moon; the others are much smaller. Jupiter is over 483,000,000 miles from the sun. Its period of revolution about the sun is over eleven of our years. Jupiter was the chief god of the ancient Romans.



Courtesy Lowell Observatory

Fig. 144.—Saturn
Note the inner and outer rings.

Saturn. The sixth planet is Saturn (Fig. 144). It is about 886,000,000 miles from the sun. It has nine moons besides peculiar rings which encircle the planet in the plane of its equator. Although these rings appear solid when seen through a telescope they are really composed of a vast number of small particles revolving around the planet. Saturn is not quite so large as Jupiter. It revolves around the sun once in about twenty-nine of our years. Saturn was the Roman god of sowing.

Uranus, Neptune and Pluto. The seventh planet is named Uranus after the patron god of astronomy. The eighth is called Neptune, after the Roman god of the sea. Recently observers have reported a ninth planet beyond Neptune. This new planet has been named Pluto. The name is a very good one. Pluto was the god of the underworld where all was shadow. Pluto, the planet, is so distant from the sun that there can be very little light upon it.

These three planets, Uranus, Neptune and Pluto are too far away from us to be seen with the unaided eye. They are observed only by means of a telescope.

Planetoids. Revolving about the sun in orbits between those of Mars and Jupiter are a large number of comparatively small bodies called planetoids.

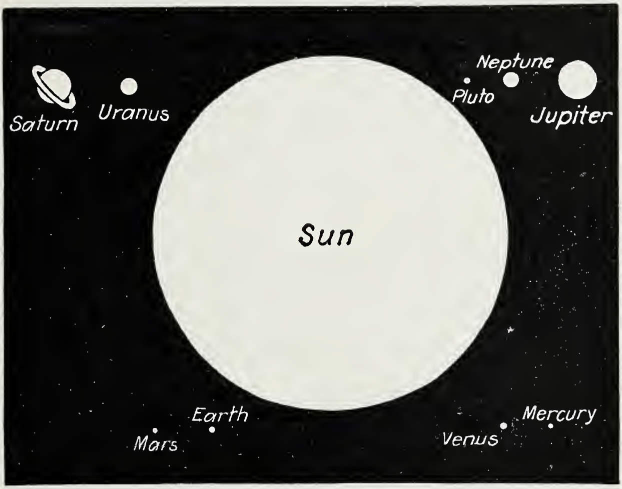


Fig. 145.—Relative Sizes of the Sun and the Planets

The Solar System. The sun and all the bodies which revolve around it is called the solar[1] system. The bodies which revolve around the sun are the planets, together with their satellites, the moons, the planetoids and comets.

The great astronomer, Sir William Herschell, pictured the solar system as follows. "On a circular field, five miles across, place in the center a globe two feet in diameter. This represents the sun. A mustard seed 164 feet away represents Mercury; a pea

[1] Sol is the Latin name for the sun.

284 feet from the center, Venus; a pea 430 feet away, the earth; a large pin-head 654 feet off, Mars; grains of sand 1,300, 2,000 feet away, the planetoids; a moderate-sized orange half a mile away, Jupiter; a small orange four-fifths of a mile away, Saturn; a cherry a mile and a half away, Uranus; and a plum two and a half miles away, Neptune."

It should now be plain why the planets wander in the heavens. It is because they are revolving each in its orbit around the sun and their positions as seen from the earth are constantly changing.

These planets shine by reflected sunlight as does our moon. They do not give off light of their own. If you could stand on one of the planets and were to look towards the earth you would see it as a spot of light in the heavens shining by reflected sunlight like other planets.

Name of Planet	Mean distance from sun in round numbers	Diameter	Number of Satellites	Period of Rotation		Period of Revolution around the Sun
	Miles	Miles		Hrs.	Min.	
Mercury	36,000,000	3,009	0	?		.24 years
Venus	67,200,000	7,701	0	?		.62 years
Earth	92,900,000	7,918	1	23	56	1. years
Mars	141,500,000	4,339	2	24	37	1.88 years
Jupiter	483,300,000	88,392	9	9	50	11.86 years
Saturn	886,000,000	74,163	10	10	14	29.46 years
Uranus	1,781,900,000	30,193	4	?		84.02 years
Neptune	2,791,600,000	34,823	1	?		164.78 years
Pluto	?	?	?	?		?

The Fixed Stars. The number of known planets including the earth is but nine. We still have the thousands of fixed stars to account for.[1] What are the fixed stars?

[1] The number of fixed stars that can be seen by the unaided eye is about 2,500. With the telescope, however, millions of them have been photographed.

Astronomers have learned that the fixed stars are suns like our own. Most of them are as bright and as hot as our sun; many of them are much hotter and brighter. Our sun is merely one of the stars in the heavens.

Since these millions of stars give us but a small amount of

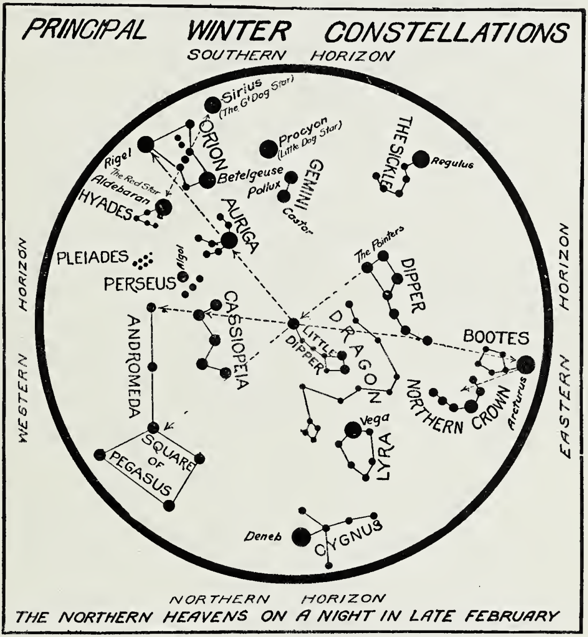


Fig. 146.—A Star Chart of the Winter Sky

light they must be extremely distant from our solar system. Proxima Centauri is the star which is nearest to the sun. It can be seen only from the southern half of the earth. How far is it from the sun?

The Yardstick of the Heavens. Proxima Centauri is so far

away that it would be hopeless to try to think of the distances in miles. The mile is too small a unit of measurement. Even the distance from the earth to the sun is too small to use as a measuring stick. To measure the distances between stars an even longer

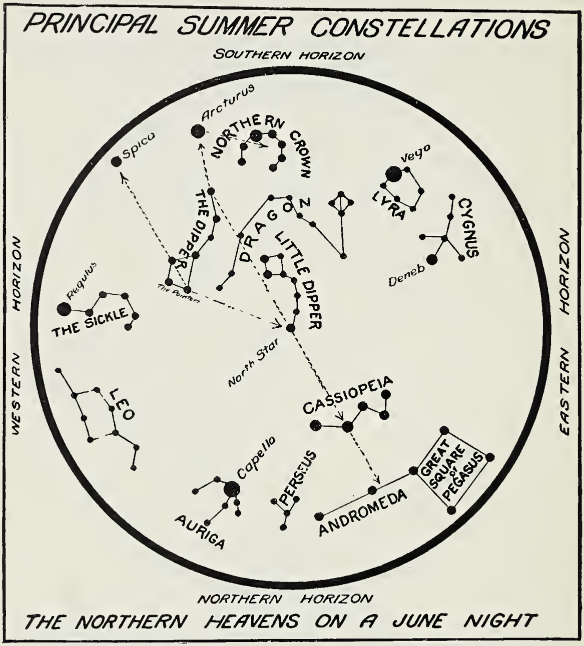


Fig. 147.—A Star Chart of the Summer Sky

yardstick is needed. Astronomers use a measure which is called a *light-year.*

Light travels at the enormous speed of about 186,000 miles a second, a distance equal to seven and one-half times around the equator of the earth. Imagine how far light will travel in a

minute, in an hour, in a day, in a year! The distance that a ray of light will travel in one whole year is called a "light-year".

The Nearest Star. The light which reaches us from the moon took one and a half seconds to travel the distance which separates the moon and the earth. Light from the sun reaches us in eight minutes. Proxima Centauri, the nearest star, is so distant that light from it travels for over four years before it reaches us. We say that it is over four light-years distant. It is difficult at first to realize how enormous this distance is. This illustration will help you.

Cobweb is the finest and lightest thread which can be obtained. It has been calculated that a pound and a half of cobweb would be long enough to encircle the earth. It would take only ten pounds of this cobweb to reach the moon. Yet it would require 500,000 tons of it to reach Proxima Centauri, the nearest star.

The other stars are still more distant. Sirius the brightest star is almost nine light-years away. Vega is twenty-six light-years distant and Arcturus forty-one light-years away. Rigel is five hundred and forty-three light-years distant and there are many much farther away than this. The light which we now see shining from Rigel left that star five hundred and forty-three years ago.

The approximate distances from the Earth in light years of some of the fixed stars, are as follows:

The Sun	8 minutes
Proxima Centauri	4.27 light years
Sirius	8.7 " "
Vega	26 " "
Ursa Major (Big Dipper) Constellation	70.80 " "
Betelgeuse	192 " "
Polaris (North Star)	466 " "
Rigel	543 " "

The Size of the Stars. Our sun is small compared with some of the larger stars. Arcturus has a diameter of twenty-three million miles. Its volume is 25,000 times as great as that of the sun. Betelgeuse has a diameter of two hundred and forty million miles and a volume twenty-seven million times greater

than the sun. The sun itself is a million times larger than the earth. Betelgeuse is not only larger but it is also 1,200 times as bright as the sun. Betelgeuse may be seen with the unaided eye but if you were only one-half as far from the sun as you are from Betelgeuse you would be unable to see the sun without the aid of a powerful telescope.

The colour of the stars tells us much about them. When the bright yellow stars are examined through the spectroscope they are found to be, both in temperature and composition, very much like our own sun. The bluish stars are hotter and are composed mainly of hydrogen gas. Many of the duller reddish stars are suns, which, having lost much heat, are cooler than ours.

Fig. 148.—A Section of the Milky Way, near the Star Alpha Cygni

The Milky Way. You may have noticed across the heavens a hazy band of light, called the *Milky Way*. It is composed of uncounted millions of stars, so distant that we do not see them individually with the unaided eye. Through the telescope the Milky Way is revealed as great clusters and groups of stars the size and distance of which we can only guess.

Courtesy Mount Wilson Observatory

Fig. 149.—A Cloudy Nebula in Cygnus (the Swan)

Courtesy Yerkes Observatory

Fig. 150.—A Spiral Nebula

Nebulae. The telescope also reveals in certain parts of the heavens cloudy patches of light which have been named nebulae (Figs. 149, 150). There are several kinds of nebulae. Some are cloud-like in shape. Other nebulae are spiral. The spiral nebulae are thought to be whirling in space. The spiral nebulae are thousands of light-years away.

Spiral nebulae are thought to be not single stars but large groups of widely separated stars many times more distant than the farthest of the fixed stars of our group. To an observer at a point as distant as the spiral nebulae are from us, the light of our group of fixed stars, including our sun, would be merged into a soft glow and would be seen as a spiral nebula.

Comets. Comets (Fig. 151) create a great deal of interest whenever they appear. Many superstitious people believe that comets are forerunners of evil and are placed in the sky to warn us of disaster to follow. The telescope, however, reveals that comets are bodies which shine by reflected sunlight. Most of the comets which we see, belong to the solar system and revolve around the sun in orbits. Since comets are usually small we see them with the unaided eye only when their orbits come near to the earth.

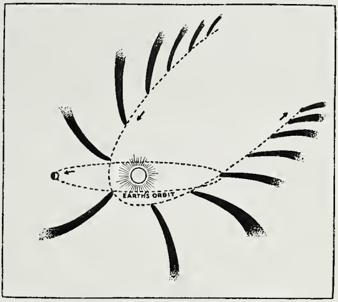
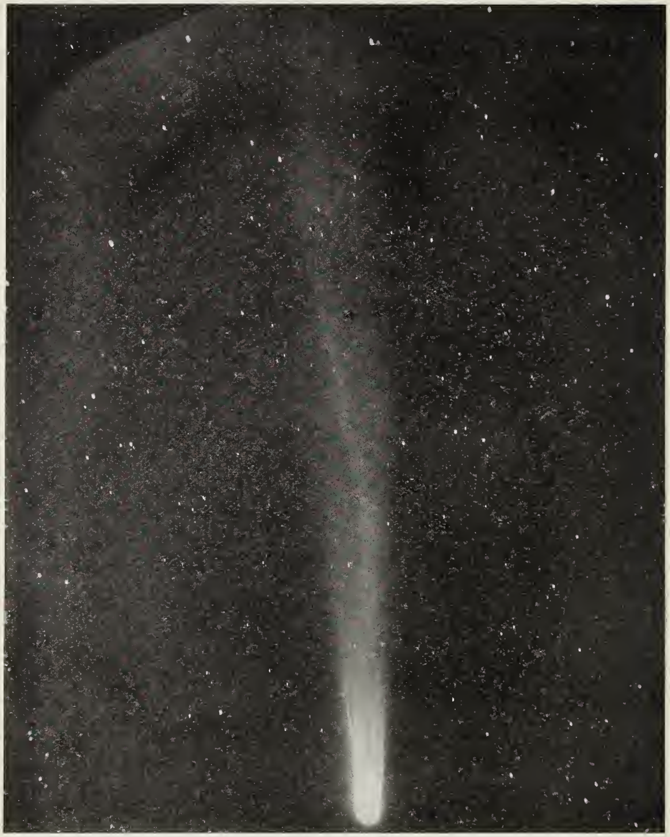


Fig. 151.—A Comet Passing Around the Sun

Notice that the tail always points away from the sun.

One of the largest and most peculiar of the comets is Halley's comet (Fig. 152). Its orbit is very elliptical in shape. It revolves around the sun once in every seventy-six years. The last time it appeared was in 1910. You may see it for yourself when it returns in 1986.

As some comets approach the sun a remarkable change occurs



Courtesy Lowell Observatory

Fig. 152.—Halley's Comet As It Appeared May 7th, 1910

in their appearances. A streamer of light appears behind them. This is called the tail of the comet.[1]

Many people have feared terrible consequences to the earth should it chance to pass through the tail of a comet. This actually has happened several times. The material of the comet's tail was so thin that it had no noticeable affect upon the earth.

Fragments From Space. Comets are rarely seen, but on any clear night you may see "shooting stars", or meteors. Meteors are not stars. They are small pieces of rock which are travelling through space at a great speed. As they near the earth they fall towards it. As they enter the earth's atmosphere and fall through it their speed and the friction of the air cause the fragments to become hot and incandescent (or glowing). This causes the streak of light which is commonly called a shooting star. Most of these fragments from outer space are burnt up before they reach the earth's surface. Sometimes one of them does reach the ground before it is all burnt. Such a stone which reaches the earth's surface is called a meteorite. Many museums have meteorites on exhibition.

Guide Words

fixed stars	planets	Mercury
Venus	Mars	Jupiter
Saturn	Uranus	Neptune
Pluto	solar system	Proxima Centauri
light-year	milky way	nebula
comet	meteor	meteorite
reflected sunlight	stars	satellites

Signpost Sentences

1. The .... are suns much like our own but are extremely remote from us.

[1] Scientists are not agreed as to the cause of these tails. Some think that the pressure of the sunlight drives out particles from the body of the comet to form the tails, while others think that the particles are driven out by an electrical force resulting from similarly charged particles of matter on the surface of both the comet and the sun. You will understand this better when you have studied the chapter on electricity. The tail of the comet always points away from the sun and as the comet moves farther and farther away from the sun the tail is gradually drawn back again into the main body of the comet and thus finally disappears.

2. The planets are worlds revolving around the sun. Our earth is a ....

3. .... shine by their own light.

4. Planets shine by ....

5. The planets appear to move among the ....

6. Some of the planets have .... or moons revolving around them.

7. A .... is the yardstick used to measure the distance between stars. It is the distance that light travels in a year.

8. The .... consists of the sun, the planets with their satellites, planetoids and comets.

9. Including the earth there are nine .... Only five of these can be seen with the unaided eye.

10. .... is the most recently discovered planet.

Problems on the Chapter

1. What difference is there between a fixed star and a planet as seen by the unaided eye?
2. What is the real difference between a planet and a fixed star?
3. What planets are farther from the sun than the earth?
4. What are the difficulties which prevent astronomers from observing Venus clearly?
5. What is a meteorite?
6. In your Science Record Book, draw a diagram showing all the planets of the solar system.
7. Name the unit which astronomers use to measure the distances between the fixed stars.
8. What is meant when we say that a star is forty-one light-years distant?
9. Of what is the Milky Way composed?
10. At one time it was thought that disaster would follow if the earth moved through a comet's tail. How do we know that this is not true?
11. Do stars ever fall?
12. What causes "shooting stars"?

Special Problems

1. What reasons have we for believing that the planet Mercury could not be inhabited?
2. What arguments are there for and against the theory that Mars is inhabited?
3. Why can't we see the stars during bright daylight?
4. Why is Venus sometimes a morning star and sometimes an evening star? Why can it never be seen except just before sunrise or just after sunset?
5. Light travels at the rate of about 186,000 miles a second. How far will it travel in a year?
6. As the year progresses different constellations of stars are to be seen. Can you account for this?
7. What has been learned from the colour of stars?

Home Projects

1. By means of the stars map (Fig. 138) locate Vega, Polaris, Rigel, The Dipper, Andromeda and Taurus.
2. Make a star chart of your own. Mark at least twenty of the largest and brightest stars. Note the colour of each star. Try to find the names of the stars you have marked.
3. On a clear night try to locate the Milky Way.
4. In star books read the stories which led to the naming of the stars. Do you believe these stories to be true?
5. Examine a group of stars with the unaided eye. Count the stars in the group. Then examine the group again through a telescope or field glass. How many more stars can you see in the group?
6. You can make star photographs with a small camera. Although stars give out too little light to allow you to take snapshots of them you can photograph them in another way. Place the camera so that it points to the stars you wish to photograph. Be sure that the stand which holds it does not move. Now open the shutter of the camera and leave it open for an hour. You will be rewarded with a very interesting photograph when the picture is developed and printed. Take two more photographs in the same way. Take the first pictures with the camera pointing at the stars overhead and the second one with the camera pointing directly at the pole star. Explain the reason for the differences of the star paths in the two pictures.
7. Look up and read the biographies, or life stories, of at least two of the following astronomers: Galileo, Copernicus, La Place, Sir William Herschell, John Kepler. Give an account of these life stories to the class.

Practical Applications

The science of astronomy has enlightened the world and has reduced superstition concerning the stars. Educated people no longer believe in "lucky" and "unlucky" stars. They now know that the position of the stars and planets in the sky can not affect their lives for good or bad. When comets appear in the sky now they awaken our interest and not our fear. Enlightened governments spend large sums to increase our knowledge of the stars. One of the largest astronomical observatories in the world was built by the Canadian people at Victoria, B.C. (Fig. 153). By means of it many important astronomical discoveries have been made by the scientist in charge of this observatory, Dr. J. S. Plaskett.

UNIT VI

APPLIED ASTRONOMY

CHAPTER XVI

APPLIED ASTRONOMY

Can you answer these questions?

1. A boy who was born in Australia took a trip across the Pacific Ocean to Canada. When he arrived he told a Canadian friend that he was thirteen years of age when he left Australia, but that while crossing the ocean he had two birthdays and yet he was only fourteen years old when he reached Canada. Could this be possible?

2. One evening a radio announcer said, "At the stroke of the gong it will be 9.00 p.m." A listener remarked, "He is wrong, my clock reads 8.00 p.m." Could both have been correct?

3. If you discovered a map of a small island showing the location of hidden treasure do you think you could find the island when the only information given on the chart was Lat. 14° 40′ 30″ N. Long. 121° E.

4. Why does the pole star remain fixed above the north pole while all the other stars in the sky appear to move?

5. Are a minute and a second of longitude the same as a minute and a second of time?

Guiding Stars. Astronomy has been of great service to mankind because it has answered many questions concerning the universe in which we live. Not only has it increased knowledge but it is of great practical value as well. Ever since men have sailed the oceans they have depended on the fixed stars to guide

them. From such knowledge gained in the course of time a science of navigation has been built up. This science makes it possible to sail ships or to guide aeroplanes to their destinations.

Long before the mariner's compass was invented sailors used to watch for the north star or pole star, because its position showed the true north.

Fig. 153.—The 72-inch Reflecting Telescope of the Dominion Astrophysical Observatory, Victoria, British Columbia
This is one of the largest telescopes in the world.

The north star is almost directly above the north pole. The north end of the axis of the earth always points in its direction. You have already observed that the stars appear to move in the heavens as the earth rotates. At first glance they all appear to move from east to west. The north star, however, does not move like the rest. It remains fixed because it is in direct line with the axis of the earth. If you observe closely you will see that the other stars do not appear to move directly from east to west but seem to rotate around the north star. This fact will be more noticeable if you examine the stars in the neighbourhood of the north star. If you could stand at the north pole you would notice that the north star directly above your head would be the centre around which all the other stars would circle. This is as it should be, since the apparent movement of the stars is caused by the rotation of the earth.

Finding the Latitude. By means of the north star you can not only locate the true north on the surface of the earth but you can also determine your distance north of the equator. If you could stand at the north pole the north star would be in the zenith directly over your head. As you moved south towards the equator the north star would appear to move lower and lower in the northern sky until at the equator it would be just visible above the northern horizon (Fig. 154). You thus see that the height of the north star above the horizon is a measure of your distance from the equator.

Distance from the equator, either north or south of it, is called *latitude*. For convenience in measuring distance north or south of the equator geographers have established *parallels* of *latitude*. These are imaginary lines which encircle the globe parallel to the equator. Between the north pole and the equator and between the south pole and the equator ninety such parallels have been drawn at equal distances from one to the next. The distance from one of these parallels of latitude to the next is one degree of latitude. There are ninety such degrees between the equator and either of the poles. The parallels grow shorter as

one goes north and the last one, of course, is a spot and is the location of the north pole. The same is true in the southern hemisphere.

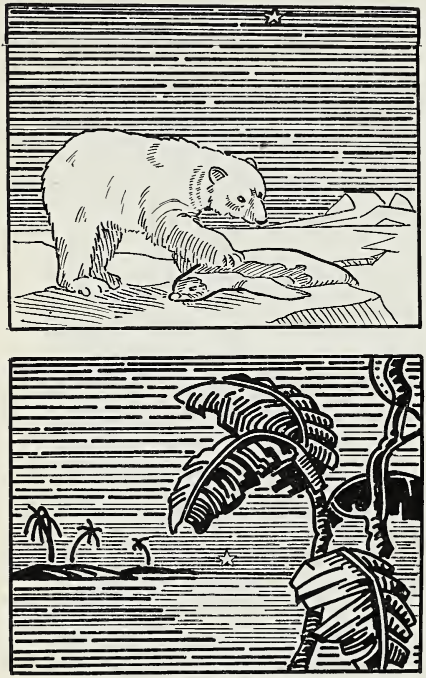


Fig. 154.
In the north polar regions the North Star appears high overhead. In the north equatorial regions it appears just above the horizon.

Thus between the equator and the north pole (or the south pole) there are 90 degrees of latitude. This distance is also just one quarter of a circle, or the quadrant of a circle, in which there are 90 degrees of angular measurement or one right angle.

Degrees of latitude are measurements on the surface of the earth which correspond with angular measurements drawn from the centre of the earth (See Fig. 155).

On maps of the globe the equator is marked "0 degrees" (0°). The parallels of latitude are marked from one degree north to 90 degrees north and from one degree south to 90 degrees south. For example the forty-fifth parallel of latitude north of the equator is called 45 degrees N. latitude.

A little thought will show you that the angle that the north star is above the horizon at any place in the northern hemisphere is the latitude of that place. At the north pole 90 degrees N. latitude the pole star is directly overhead and if a line were drawn from the pole star to the north pole it would make an angle of 90 degrees with a line drawn from the north pole to the horizon (Fig. 156). At the equator, 0 degrees latitude, the pole star is just on the horizon and of course 0 degrees above it. At 45 degrees N. latitude the pole star will be half way between 0 degrees and 90 degrees, that is, at an angle of 45 degrees above the horizon.

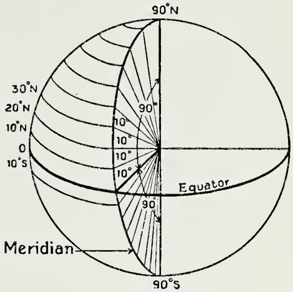


Fig. 155.—Parallels of Latitude

A degree of latitude is equal to about seventy miles on the

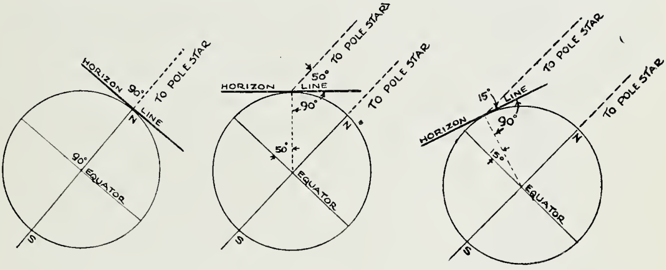


Fig. 156.

The Pole Star is so far away that a line pointing to it from any position on the earth is practically parallel to the one pointing to it from the North Pole.

earth's surface. To determine locations accurately some measurement smaller than a degree is required. For this reason each

degree is divided into sixty parts. Each part is called a *minute,* each minute is again divided into sixty parts each of which is called a *second.* These minutes and seconds are not measures of time but are measures of parts of a degree. A minute of latitude on the earth's surface is a distance of $1\frac{1}{8}$ miles and a second of latitude is 1/60 of that. In stating positions of latitude abbreviations are often used. A degree is abbreviated as °, a minute as ′ and a second as ″. A position 30 degrees, 17 minutes and 12 seconds north of the equator is abbreviated as 30° 17′ 12″ N. Lat.

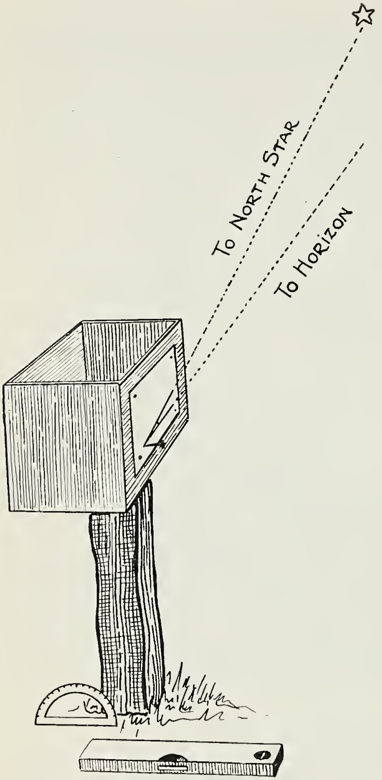


Fig. 157.—How to Find Your Latitude

You can use the north star to find the latitude of your home.

PROBLEM

To determine the latitude of a location.

Plan. Since the angle that the north star is above the horizon is the same as the latitude of a location you can determine the latitude by measuring the angle of the north star above the horizon.

Apparatus. A box, a piece of stiff cardboard or paper, a carpenter's spirit level, a nail, protractor, pencil, (Fig. 157).

Method. Put the box on a fence-post from which the north star can be easily seen. Tack the paper on the side of the box and turn the box

on the post so that the paper faces either east or west. Drive a nail about an inch or so from the lower south corner of the paper, be sure that the nail is at right angles to the paper. Turn the box until you can sight the pole star over the nail and along the edges of the paper. Place the level on the nail and sight the pole star along its upper edge. Then with the pencil draw a line along the lower edge to the nail. Without disturbing the box and still keeping the level on the nail lower it until the level indicates that it is horizontal. Then draw another line along the underside of the level to the nail. This horizontal line will point to the horizon. The angle between the two lines which meet at the nail will indicate the number of degrees which the pole star is above the horizon. Place the centre of the protractor on the nail and the base of it along the horizontal line and read where the line to the star cuts across the protractor.

Observation. How many degrees above the horizon did you find the star to be?

Conclusion. What is your latitude? Check your results by consulting an atlas which shows the latitude of your locality. How closely do they agree?

Another way of determining your latitude is by observing the angle of the sun above the horizon at high noon. If the sun were over the equator at all times (that is, if it were always at right angles to the plane of the orbit of the earth), it would be just as simple to get the latitude from the sun as it is to get it from the north star. The only difference would be that you would have to subtract the measured angle between the sun and the horizon from 90 degrees because the sun would be at right angles to the axis of the earth and not in line with it as the north star is. Finding latitude from the sun is not so simple, because the inclination of the earth's axis makes the sun appear to move north or south of the equator and consequently higher or lower over the horizon. The measured angle that the sun is above the horizon changes from day to day. When the latitude is determined by observing the sun the result must be corrected to take care of this daily difference. Accurate tables have been prepared so that navigators can make the correction for each day as the year progresses.

Finding the Longitude. Because of the rotation of the earth there is no fixed point like the north star by which distance east or west can be measured. Navigators have resorted to another means of determining *longitude* or their east or west location.

They take advantage of the fact that the earth rotates once in every twenty-four hours.

Suppose that a line were drawn from the north pole to the south pole through a certain point on the earth's surface. Then, as the earth rotates, from the time that this line is directly under the sun until it is under the sun again twenty-four hours would have passed. During this time the line would have travelled around a complete circle or 360 degrees. In each hour therefore the line moves through a distance of $\frac{360}{24}$ or 15 degrees.

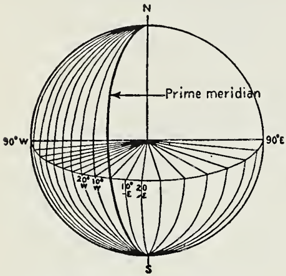


Fig. 158.—Meridians

For convenience navigators have agreed to use as a starting line an imaginary line drawn from the north pole to the south pole through the observatory at Greenwich, near London, England. This line has been named zero or the *prime meridian.* At equal distances from each other there are 360 such imaginary lines drawn from the north pole to the south pole. They are spaced one degree apart and are numbered from 1 degree to 180 degrees east and 1 degree to 180 degrees west of the *prime meridian.* They are called *meridians of longitude.* They measure *longitude,* or distance east or west of the prime meridian, just as parallels of latitude measure latitude, or distance north or south of the equator (Fig. 158).

When the sun is exactly over a meridian it is twelve o'clock noon all along the meridian from pole to pole. When the sun is over the prime meridian it is twelve o'clock noon at Greenwich. One hour later, since the earth rotates from west to east, the sun will be directly over the 15th meridian—just 15 degrees west of the prime meridian. The time on the prime meridian will now be one o'clock p.m.

A navigator can determine his position east or west of the

prime meridian by knowing the difference between his time and Greenwich time. For example, if it is three p.m. by Greenwich time when the navigator by observing the sun finds that it is high noon where he is, then he is removed three hours from Greenwich. Since Greenwich time is after noon he must be west of the prime meridian 3 x 15 degrees or 45 degrees. His longitude is therefore 45° W. Long.

It is clear that in order to determine his longitude a navigator must know the time at Greenwich. For this reason a ship carries a very accurate clock called a *chronometer*. This chronometer registers the time as at Greenwich. By taking the difference between the time of the clock and the time on the ship when it is high noon the longitude of the ship can be calculated.

Since radio has come into use the Greenwich observatory broadcasts its time regularly that ships may check their chronometers and so avoid errors.

In order to observe the sun accurately and so find his time the navigator uses an instrument called the *sextant* (Fig. 159). He is said to "shoot" the sun at noon. By means of the sextant he can tell not only when it is high noon but he can measure also the angle of the sun above the horizon and so may find his latitude as well as his longitude. If his observations are carefully made he should be able to tell the exact location of his ship.[1]

Standard Time. Formerly each community depended upon the sun for correct time. When the sun was directly overhead it was twelve o'clock noon. When railroads and other rapid methods of travel were developed this led to confusion because no two communities had exactly the same time. Imagine the difficulties of trying to make a railroad time-table in Canada if every town had its own time. To overcome this difficulty

[1] In navigation the sextant is chiefly used to determine the latitude by the meridian altitude of the sun or of certain fixed stars. The usual method of determining longitude is by the comparison of local time with Greenwich time, the former being found by observing the rising and setting of heavenly bodies rather than by the meridian passage. While the method for time determination given in the chapter, is possible, it is not so practical as the method here referred to.

"Standard Time"[1] was introduced. The country was divided into five belts. Each belt contained 15 degrees of longitude. The time of each belt is one hour later than the one west of it and one hour earlier than the one east of it. Twelve o'clock noon for each belt is determined when the sun is over the central meridian. For reasons of convenience adjoining communities near the edge of a belt are grouped in the same belt. That is why the belts do not appear regular upon the map (Fig. 161). If you were to travel from Vancouver to Halifax you would turn your watch ahead one hour as you entered each of the time belts. The time on your watch would then be four hours ahead of the time in Vancouver. If you were to continue your travels and go all the way around the world, by the time you got back to Vancouver, your watch would have been turned forward twenty-four hours, and it would be a whole day ahead of the Vancouver clocks. When you consider this you

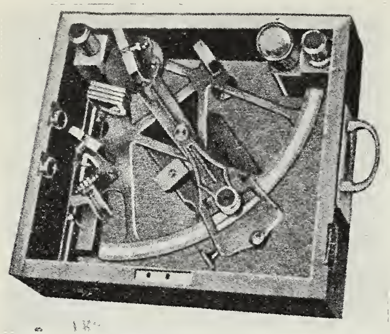
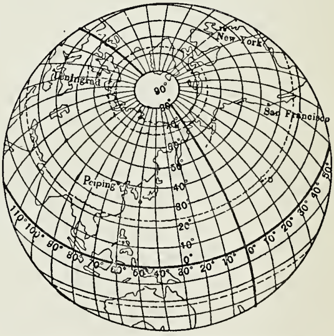


Fig. 159.—A Sextant Inclosed in its Case

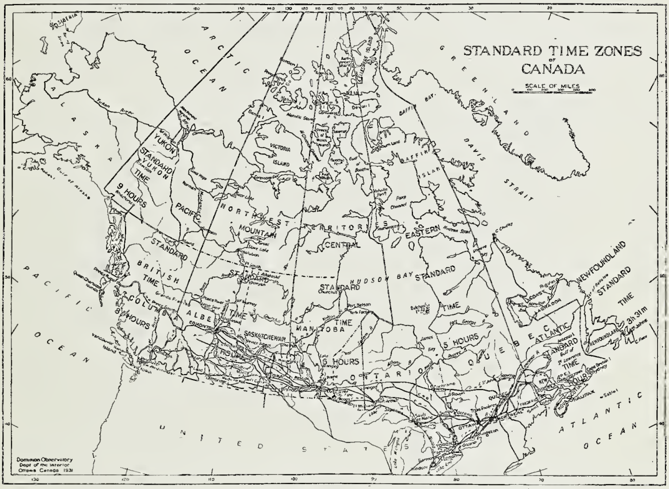


From Wood and Carpenter: Our Environment: How We Use and Control It (Allyn and Bacon).

Fig. 160.—Longitude and Latitude

[1] It is interesting to note that *standard time* was devised by a famous Canadian engineer, Sir Sandford Fleming, at one time chancellor of Queen's University.

will see that there will be a difference of a whole day and your calendar will be a day ahead of those in Vancouver. In order to prevent this from happening a date line has been established by international agreement. The line follows the 180th meridian with a few bends in it to include neighbouring communities all on the same side of the line (Fig. 162). When a ship crosses the date line going east, that is toward America, the calendar is set back a day. That means that two succeeding days have the same dates. On the other hand when the ship crosses the date line going west a date of the calendar is cancelled.



Courtesy Survey Branch, Dept. of the Interior, Ottawa

Fig. 161.—Standard Time Zones of Canada

GUIDE WORDS

navigation	latitude	prime meridian
longitude	meridian	minute
sextant	degrees	international date line
second	standard time	fixed stars
angle	navigators	Greenwich
noon	parallel	

Signpost Sentences

1. Because of the rotation of the earth, ... when seen in the northern hemisphere, seem to revolve around the pole star.
2. .... use either the sun or the fixed stars to guide them.
3. Latitude is distance north or south of the equator, measured by .... of latitude.
4. Longitude is distance east or west of the .... measured by degrees of longitude.
5. Latitude can be determined from the .... of the pole star above the horizon. It can also be determined from the angle of the sun above the horizon at ....
6. The .... of a place can be determined by noting the difference between the time at the prime meridian and the time at the place.
7. .... belts were made to avoid the confusion which resulted from each community having its own local time.
8. The .... is situated along the 180th meridian.
9. The prime meridian extends from the north pole to the south pole through the observatory at ...., England.

Fig. 162.—International Date Line

Questions on the Chapter

1. Why is the pole star such a useful guide to mariners?
2. Why do the fixed stars seem to revolve around the pole star?
3. Where would the pole star appear to be if you were standing at the north pole?
4. Where would the pole star appear to be if you were standing at the equator?
5. How many miles on the earth's surface does one degree of latitude represent?
6. How many degrees are there in a circle?
7. Through what observatory does the prime meridian pass?
8. How is the latitude of a place determined?
9. How is longitude determined?
10. What is a parallel of latitude?
11. What is a meridian of longitude?
12. How many standard time zones are there in Canada? What is the name given to the time in each zone?
13. Where is the "international date line"?
14. What is a sextant?

15. When latitude is determined by observing the sun what corrections must be made?

Special Problems

1. Describe how you would use the pole star to determine your latitude.
2. From a map of the world determine the latitude and longitude of your own town or city.
3. In the same way determine the latitude and longitude of the following places: London, England; Hong Kong, Honolulu, Ottawa.
4. Locate on the map the following places: 22 degrees N. Lat. and 15 degrees E. Long.; 45 degrees S. Lat. and 45 degrees W. Long.; 30 degrees S. Lat. and 30 degrees E. Long.; 37½ degrees S. Lat. and 145 degrees E. Long.
5. If the chronometer on board a ship registers 4.30 p.m. when the sun is at high noon, what is the longitude of the ship?
6. What is the time at Ottawa, Ont., when the time at Victoria, B.C. is 7.00 a.m., 7.00 p.m., 10.00 a.m., 12.00 noon?
7. What is the time at Victoria when the time at Winnipeg is 11.00 a.m.?
8. When the time at Ottawa is 1.00 a.m., what is the time at London, England?
9. Radio listeners at Halifax, N.S. can receive radio programmes until 4.00 a.m. On the Pacific coast most of the radio broadcasting ceases at 12.00 p.m. Can you account for this difference?
10. A radio programme was broadcast from London, England, so that it would be heard at 7.00 p.m. at Regina, Sask. At what time was the programme released in London?

Home Projects

1. The compass needle does not everywhere point to the true north. Determine how far it deviates or points away from the true north where you live.

You can find the true north by observing the pole star. You can also find it by noting the direction of the sun's shadow at high noon. To do this drive a stick into the ground. Be sure the stick is perpendicular. At noon the shadow will be due north. Check the compass needle with the shadow.

2. Determine your latitude by following the directions given on page 214.
3. You can use your watch as a compass. Point the hour hand (the smaller one) towards the sun. North lies along the imaginary line which divides the angle between the hour hand and 12 o'clock. Can you tell why this should be so?
4. Learn how to make a sun dial.

Practical Applications

1. Navigation would be extremely difficult without an accurate knowledge of star positions.
2. Geographers depend upon the science of astronomy for constructing accurate charts and maps.
3. Correct time is determined in the astronomical observatories.
4. Explorers should be trained in the science of navigation.

UNIT VII

THE STRUCTURE OF THE EARTH

CHAPTER XVII

THE STRUCTURE OF THE EARTH

Can you answer these questions?

1. How was the world formed?
2. How were the mountain ranges formed?
3. What causes volcanoes?
4. How did the coal get into the coal mines?
5. How did scientists discover that giant reptiles, which now no longer exist, used to live on the earth ages ago?

A Rock-bound History Book. Much of the early history of civilization was written on stone by early man. From the queer pictures of wild beasts painted by the cave dwellers to the writings chiselled on the stone walls of the Egyptian temples is a long and strange story. There is a stranger story and a much older one written in the rock formations of the world. It is, however, more difficult to read. *Geologists* are scientists who have learned to read the story of the rocks. The facts which they have learned form one of the special sciences, called *geology.*

Geologists presume that at one time the solid portion of the earth's surface was *igneous rock.* Igneous rock is rock which at one time was melted or molten. It forms the main part of the crust of the earth. It is really the foundation stone upon which the other rocks have been built. Why was the original igneous rock molten? How was it first formed?

Scientists have tried to answer these questions by reasoning in

the following way. Since the igneous rock was formed by the cooling of molten matter they believe that the earth itself was at one time an intensely hot, molten mass. Although they have not been able to say exactly why the earth should have been in a molten state some scientists have theories to account for it. One of these theories was suggested about one hundred years ago by the French scientist, La Place. He thought that the solar system, of which the earth is a part, has been a nebula or a great cloud of hot vapour whirling in space (Fig. 150). As the vapour of the nebula cooled, a large central part condensed to form our sun. The outer portions of the nebula formed rings of hot gas which later cooled and condensed and formed the planets. Because the planets were much smaller than the sun they cooled off more quickly. La Place's theory is called the "nebular hypothesis" or "nebular theory".

Quite recently other scientists have brought forward a different theory. These scientists think that at one time the earth was actually a part of the sun. They believe that at some remote time a large star passed very close to our sun. The gravity of the visiting star caused a tide to rise in the molten matter on the sun's surface. As the star came closer the tide became so high that masses of molten matter were drawn off from the sun. These masses were sent revolving around the sun as the visiting star continued on its way. As the revolving masses cooled they formed the planets. Our earth, they think, is one of the planets, so formed.

Which one of these theories is correct may never be known. They may both be wrong. However, one thing is certain: the *spectroscope*[1] has revealed that the sun is composed of materials similar to those found upon the earth. Hence it is quite probable that the sun and the earth were at one time part of the same molten mass.

The Birth of the Mountains. As time passed, the earth cooled. A solid crust of igneous rock formed upon its surface.

[1] See page 171.

As the earth continued to cool the hot interior contracted faster than the crust. This contraction caused the crust to wrinkle and fold (Fig. 163). These wrinkles and folds were the beginning of our present day mountain ranges and continents. The first mountain ranges to be thrust up have been worn down or eroded by the action of air and water until today they are merely rounded hills. The Laurentian mountains of Canada are an

Fig. 163.—The Folding of the Earth's Crust

example of a mountain range which was eroded in this way. The Rocky mountain range is an example of a more recently formed range. The Rocky mountain peaks are still high and jagged.[1] In time, however, they too will become eroded. (If you do not recall how erosion takes place it will be well, at this time, to review Chapter VI. You will learn there how the weather converts hard rock into soil.)

[1] Before the more recently formed Rocky Mountains were thrust up the crust of the earth had been covered to a great depth with sedimentary rock. This explains why sedimentary rock predominates in these mountains.

The silt from eroding mountains is washed into the ocean where it is deposited. The coarser particles of silt settle first. The finer particles are carried farther out to sea.

The central plain of North America was at one time the bed of a shallow ocean. Sediment from the Laurentian and Appalachian mountains, and later from the Selkirk range was deposited in this ocean (Fig. 164). The movement of the crust of the earth caused the continent to rise slowly. The central ocean became smaller until it completely disappeared. The ancient ocean bed became the central plain of North America.

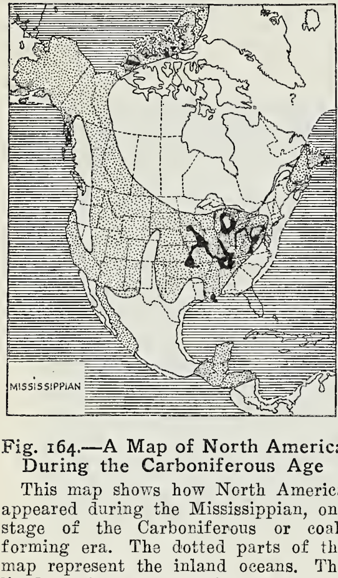


Fig. 164.—A Map of North America During the Carboniferous Age

This map shows how North America appeared during the Mississippian, one stage of the Carboniferous or coal-forming era. The dotted parts of the map represent the inland oceans. The lined portions are oceanic waters. The white portions are the probable land areas. The details of the coast lines changed from time to time and cannot be shown for certainty for any one period. Notice the possibility of land connections with Europe by way of Baffin Island and Greenland, and with Asia, by way of the land in the Berhing Sea.

In the Far Past. During the ages in which these changes were taking place vast forests, quite unlike our modern ones, grew along the edges of the inland ocean. Huge tree-like ferns bordered swamps and marshes where our western prairies now lie (Fig. 165). Strange beasts fed upon the plants of the marshes and forests. They were lizard-like *amphibian* animals which were at home either in the water or on the land (Fig. 166). The water of the seas and swamps teemed with peculiar fish, quite unlike any which are living today. In

the air giant insects a foot in length clattered their way about the gloomy, flowerless forests. The age in which these forests existed is called the *Carboniferous Age*, because it was during this age that great coal deposits were made.

How did geologists learn all this early history of the continent? The rocks of the earth are the pages on which it is written. One of the first persons to suggest that much was to be learned from the rocks was Xenophanes of Greece. Over two thousand years ago he found some oyster shells embedded in the rocks of a

From Sargent's Plants and Their Uses

Fig. 165.—Fern-Like Trees of the Carboniferous Period

mountain top. He came to the conclusion that the mountain top must have been under the sea long ago; "For," said he, "how else could the oyster shells have got there? Who ever heard of oysters climbing mountains?" It seems strange, does it not, that oysters, which have a reputation for silence, should be able to tell so much. How did the oysters get into the solid rock at the top of the mountain?

Oysters live in mud. It is evident that the mountain top which

Xenophanes studied must have been soft mud at some earlier time. On examination it was found that the rock was in layers, or *strata,* as the geologists call the layers (Fig. 167). The rock is also quite different from any of the igneous rocks such as granite. It is fine grained and chips off in flakes when struck with a hammer. How was this soft mud changed into rock?

Sedimentary Rocks. The silt brought down by the rivers settled as sediment on the floor of the ocean. Year after year the layers of sediment were deposited. As they piled up, the weight of

Courtesy Geological Survey of Canada

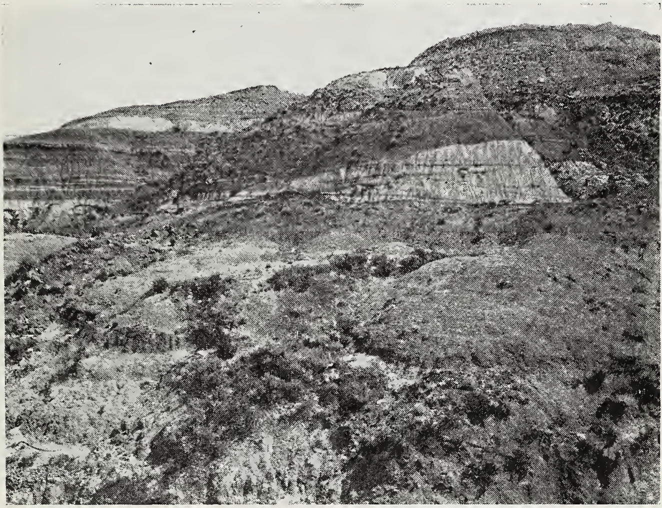
Fig. 166.—A Labyrinthodont, An Amphibian of the Carboniferous Period

the water pressed the particles of sediment into a compact mass and a chemical action of the water cemented them into rock. Because this rock is formed from sediment it is called *sedimentary rock.* Because it is formed in layers or strata it is also called *stratified rock.*

There are many kinds of sedimentary rocks. One kind is called *conglomerate.* It is formed from a mixture of gravel, clay and sand. It resembles the concrete used for foundations of buildings (Fig. 168). The action of flowing water often separates

the clay and sand from the gravel before it hardens into rock. The sand then becomes sandstone and the clay becomes shale.

Deposits of sedimentary rock are sometimes several miles in thickness. When such deposits of rock are thrust up from the ocean floor they form new mountain ranges. Such a mountain range is the one that Xenophanes examined in Greece. These



Courtesy Geological Survey of Canada

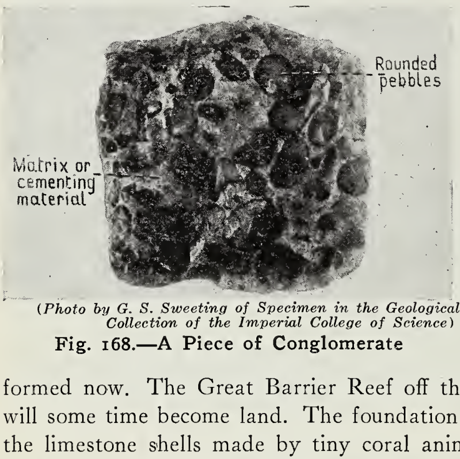
Fig. 167.—Stratified Rock

mountain ranges of sedimentary rock are themselves eroded by weathering and in turn they too make new soil.

You have learned how the original igneous rock was broken up and formed soil; how some of the soil was washed into lakes and oceans, and how it settled there; how the sediment became hardened into various kinds of sedimentary rocks; how some of the sedimentary rocks were thrust up from the ocean bed; how they in turn were broken up by the same forces which attacked

the igneous rocks and, as a result, were themselves changed into soil. The processes are going on continually. Rocks are eroded and form soil. The soil is washed into large bodies of water where it settles and becomes rock. The new rock becomes land, and so the process starts all over again. This process is called the *Rock-Soil Cycle.*

Chalk and limestone are other forms of sedimentary rocks. Chalk is made from the shells of tiny sea animals which have accumulated on the bed of the ocean. Sometimes these deposits are several hundred feet in thickness. The famous chalk cliffs of Dover, England, are an example of limestone rock formed in this manner. In some parts of the world, particularly in the warmer South Seas, limestone deposits are being formed now. The Great Barrier Reef off the coast of Australia will some time become land. The foundation of this land will be the limestone shells made by tiny coral animals.



(*Photo by G. S. Sweeting of Specimen in the Geological Collection of the Imperial College of Science*)
Fig. 168.—A Piece of Conglomerate

Many of the sedimentary deposits that were laid down in very ancient times have been subjected to intense heat and pressure by the folding of the earth's crust. The heat and pressure have caused the particles to fuse or partly melt together. Sandstone treated in this way becomes quartzite, a very hard flinty rock; shale becomes slate; chalk becomes marble. The beautiful colours you see in marble are due to minerals that got into the chalk deposits while they were forming.

Coal Formed. The same pressure and heat which caused the

sedimentary rocks to become *metamorphosed* or changed into slate and marble also caused the deep deposits of carboniferous plants to be changed into coal.

The vegetation of the carboniferous age accumulated in thick layers in the swamps. The shifting of the earth's crust caused some of the deposits to become submerged beneath the ocean.

Courtesy Geological Survey of Canada

Fig. 169.—Exposed Coal-Seam, Peace River

Sediment covered the layers. As the sediment became hardened into rock and was subjected to heat the layers of vegetation changed into coal. While the coal was forming, the heat and pressure drove from it a great deal of gas and oil. The gas and oil collected in pockets or folds of the stratified rock. Today oil wells are drilled into the ground, and when a well penetrates one of the pockets the gas and oil come to the surface (Figs. 170, 171, 172).

Animals of the Past. Besides oyster shells there are other animal and plant remains to be found in sedimentary rocks. Such remains are called *fossils*. From fossils scientists have been able to learn a great deal about the animal and plant life of prehistoric times. The fossils are found in sedimentary rocks. As the silt, from which the sedimentary rocks are made, was being deposited, the dead bodies of animals and the leaves and twigs of plants became mixed with the mud. The mud packed tightly about them. Later when the mud hardened into rock the fossil impressions remained. Geologists are able to estimate roughly the time when a foss'l animal or plant lived by noting the depth of the stratified rock above it. Their estimates give some of the fossils an age of several million years.

Fig. 170.—An Oil Well
Pressure of gas or oil in the pocket below causes the oil to gush from the well. Such a well is called a "gusher".

In the lower strata of the very oldest sedimentary rocks geologists find the fossils of little hard-shelled sea creatures which had many legs. They are called *trilobites* (Fig. 173). Some of the trilobite fossils are said to be over fifty million years old. They are found in great numbers and they must have been very numerous in the prehistoric seas. There are none of them living

Fig. 171.—Turner Valley Oil Field, Alberta

today. They have become *extinct.* They became extinct millions of years ago. A study of fossils shows that there were a great many different kinds of animals which have become extinct.

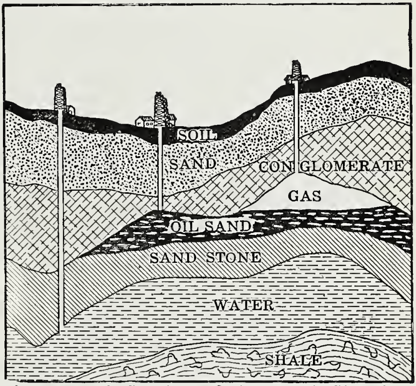
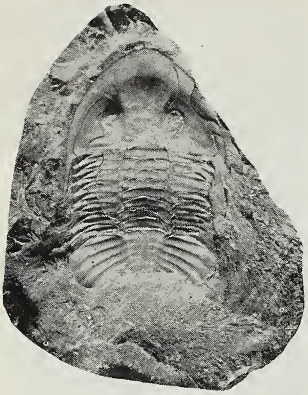


Fig. 172.—A Section of the Earth Showing How Oil and Gas Are Obtained

As the geologists study the higher and more recently formed strata they notice that the forms of life change greatly. For instance above the strata in which the trilobites are numerous they find fossils of a kind of fish. In still higher strata they find the fossils of amphibians. These were strange animals, which,

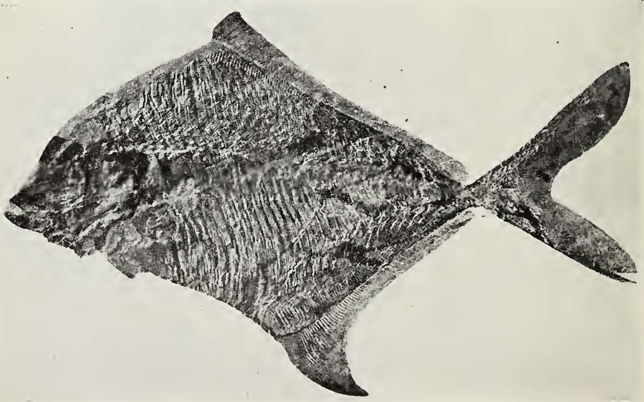


Courtesy Geological Survey of Canada

Fig. 173.—Fossil Trilobites

These are found only as fossils. Trilobites are now extinct.

like fish, had gills for breathing while in the water and also had lungs for breathing on land (Fig. 166). In the layers above those in which fossil amphibians have been found geologists find the remains of *dinosaurs* or lizard-like reptiles (Figs. 175, 176). Some of these are of enormous size. A fossil skeleton of a dinosaur which is eighty-seven feet long has been unearthed. These dinosaurs were probably the largest creatures which have ever lived upon the earth. With the dinosaur remains are found the skele-

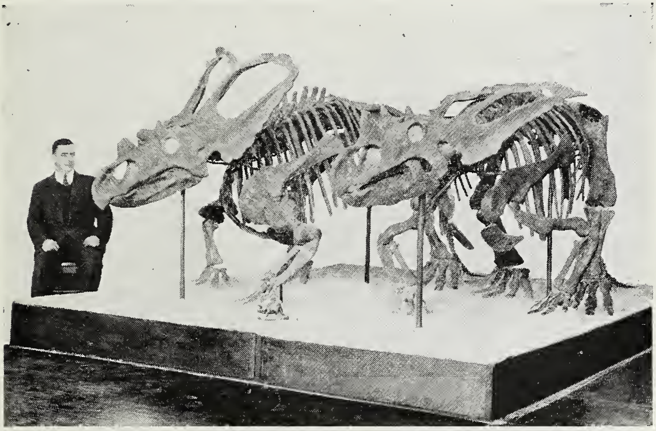


Courtesy Geological Survey of Canada

Fig. 174.—A Fossil Fish

tons of *pterodactyls*. They were flying lizards with bat-like wings. In more recent strata are found the remains of primitive birds. The most recently formed fossils resemble many animals living today.

Who would have thought that such a strange story lies buried in the rocks! The story is being continued now. Fossils are still



Courtesy Geological Survey of Canada

Fig. 175.—Fossil Skeletons of Dinosaurs Dug Up in Red Deer River Valley, Alberta

Many fossil dinosaurs have been found at Red Deer River Valley. This indicates that the monsters roamed over what is now Western Canada many millions of years ago.

being formed. Mountains are still being raised and continents are still in the process of being built. Nor have geologists as yet learned all the facts about the earth. They have not been able to go far into the earth's interior. However, they have learned much about it by observing other things. While boring for oil wells and digging mines they have learned that the deeper into the earth one goes the hotter it becomes. Therefore the interior of the earth

must be very hot, hot enough to melt the rock of which the earth is composed if it were not for the fact that the pressure of the surface rock prevents the interior from melting. Scientists have been able to prove that the interior of the earth is as rigid as steel. They do this by studying the speed with which earthquake shocks travel through the earth. They also learn about the interior of the earth by studying volcanoes.

Courtesy Geological Survey of Canada

Fig. 176.—Dinosaurs Reconstructed to Show How They Might Have Looked When They Were Alive

How Volcanoes Start. In some regions the crust of the earth becomes arched. This causes mountain ranges to be formed, as you have read at the beginning of the chapter. When this happens the surface pressure is taken off the interior rock. The removal of the pressure allows the rock to melt. If the upper surface cracks, the melted interior rock erupts or flows upward

through the crack. The melted rock is called *lava* and the crack or hole from which it flows is called a volcano (Fig. 177). Volcanoes which are near the ocean often erupt with explosive force. This is caused by steam. Water from the ocean seeps through cracks in the rock until it sinks to the depth of the hot interior rock. The water forms steam and the pressure of the steam causes an explosion. Pumice-stone comes from volcanoes which erupt in this way.

Fig. 177.—Crater of Vesuvius During Eruption

Guide Words

geology	slate	metamorphic
conglomerate	dinosaur	central plain
fossils	stratified	spectroscope
carboniferous	marble	shale
sedimentary	coal	extinct

nebular theory	igneous	trilobite
sandstone	pumice	lava
impressions	limestone	rock-soil cycle
tidal theory	reptile	amphibian
quartzite	volcano	rock formations
prehistoric	chalk	mountain ranges

Signpost Sentences

1. Much of the early history of the earth has been learned from .... on its surface.
2. The materials which make up the earth are similar to those discovered on the sun by means of the ....
3. The earth's crust was originally .... rock.
4. The wrinkling of the earth's crust was the beginning of the .... and continents.
5. .... rocks have been formed from the eroded materials of other rocks.
6. Sedimentary rocks are ....
7. .... rocks are sedimentary or igneous rocks of which the original nature has been changed by heat and pressure.
8. The great .... of North America was the bed of a shallow ocean.
9. The coal deposits of today were formed from the vegetation deposited during the .... age.
10. The nature of life on the earth before the time of man is learned by studying ....

Questions on Chapter XVII

Fill in the Blanks:

Scientists who have learned to read the story of the rocks are called .... The facts which have been learned about rocks form a special science called ....

The earth at one time, was .... mass. It is thought that the earth was part of the .... As the earth cooled .... formed on its surface. As the interior of the earth cooled further the surface became .... because ....

The peaks of the Laurentian Mountains are .... because these mountains have been .... by weathering. Material from these mountains helped to build .... of North America.

Silt is deposited by .... The layers of silt harden to form .... rock. Another name for the rock is ....

Rock which is: 1. formed from clay is called ....; 2. from sand is called ....; 3. from sand clay and pebbles is called ....; 4. from the shells of sea animals is called ....

Vegetation from forests which grew in the carboniferous age was changed into .... by .... and .... At the same time pockets of .... and .... were formed.

Plant and animal remains found in rocks are called ....

Special Problems and Practical Applications

1. A thorough knowledge of geology helps men to find oil wells and mineral deposits.
2. On an outline map of Canada mark the coal-mining areas. Can you tell what the nature of the country above the coal mine was like before the coal was formed.
3. From an encyclopaedia or other suitable book learn the story of the dinosaurs and tell it to the class.
4. Is there any evidence to show that the country in which you live was ever under water?

UNIT VIII

THE IMPORTANCE OF AIR IN OUR DAILY AFFAIRS

CHAPTER XVIII

PUTTING AIR TO WORK

Can you answer these questions?

1. When a football is pumped up is it heavier or lighter than when it is flat?
2. How much does the air in your class room weigh?
3. Could a large steel tank be crushed by the weight of the air?
4. How high is the air?
5. What is a vacuum?
6. What is suction?
7. Why does suction raise liquids in tubes?
8. Can air stop a train?
9. How do aviators measure their distance above the ground?

Air is Real. James and Henry were playing together.

"Here is an empty bottle," said James, "let us throw stones at it."

"You are mistaken; the bottle is not empty," said Henry, who had studied science.

"I cannot see anything in it," said James.

"It is full of air," Henry maintained.

"Oh! but air is nothing," argued James scornfully.

"Oh, no! Air is as real as the stone you have in your hand," the other insisted.

"You will have to prove that to me," retorted James.

"I can prove that air occupies space," replied the other.

How did Henry prove it? Could you have proved that air occupies space if you had been in Henry's place? No doubt you would have done as he did. You would have secured a dish of water and would have forced the bottle mouth downwards into it, in order to show James that water would not go into the jar and that as long as the jar contained air nothing else could enter it. In other words, air like any other substance occupies space. James was hard to convince. He said, "Even if the air does occupy space it cannot be seen, nor does it weigh anything as the stone does. So, after all, it is not real."

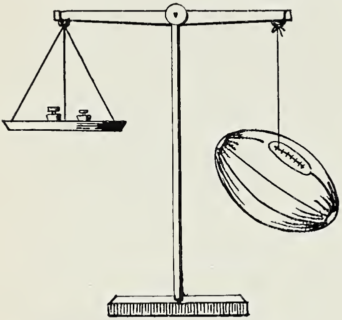


Fig. 178.—Weighing Air

How would you answer an argument like that? Of course being a scientist, you would use the scientific method to determine whether or not air does have weight.

PROBLEM

Does air have weight?

Plan. If air does have weight it must add something to the weight of the container which holds it. A football should weigh more when it is filled with air than when it is empty.

Apparatus. A set of balances, weights a football and a bicycle pump.

Method. Squeeze all the air out of the football and weigh it. Then force air into it by means of a bicycle pump and weigh it again.

Observation. Did the football weigh more when it was full of air than when it was empty?

Conclusion. Has air weight?

Air Has Weight. Such an experiment as the one with the football should convince James that air like the stone does have weight. Of course he already knows that it occupies space. *All things which occupy space and have weight are real.* You do not ordinarily notice air because it is invisible.

The air which we weighed in the football was compressed air; that is, a great deal of it was squeezed into a small space. Would it be possible to find the exact weight of the ordinary air about you? Scientists do this by weighing a steel ball full of air (Fig. 179). Then by means of a vacuum pump they exhaust or pump out all of the air from it. When the ball is entirely emptied of air they weigh it again. The weight of the air which was in the ball is equal to the difference between the weight of the ball before the air is taken out and the weight of the ball after it is taken out.

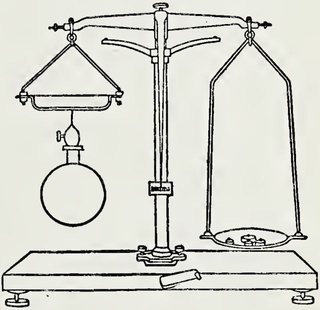


Fig. 179.—Finding the Weight of Air

By means of an accurate balance the actual weight of air can be found.

In this way they have learned that when it is weighed at sea level, a cubic foot of air weighs one-thirteenth of a pound, that is 1¼ ounces. The air in a classroom of ordinary size would weigh at this rate about one-half of a ton. It is difficult to believe that a substance which you cannot see and the very existence of which you could prove only by experiment should weigh so much. Think of the enormous weight of air on the earth. If a layer of this air were a foot deep on the surface of the earth then each square foot of surface would be carrying one-thirteenth of a pound. If a layer were thirteen feet deep or about as high as the ceiling each square foot of the earth would support a weight of one pound. If the layer were thirteen hundred feet deep the weight of the air on each square foot would be one hundred pounds. Is there any way of determining the exact weight of air on each square foot of the surface of the earth?

Air-Pressure. The scientist who first solved this problem

was Torricelli, a pupil of the astronomer Galileo. Galileo became interested in the weight of the air when his friend, the Duke of Tuscany, was unable to pump water from a deep well which had been dug on his property. The best pumps which could be obtained at the time would raise the water up to thirty-two feet but no higher. The duke asked Galileo for an explanation. Galileo suggested that it was the air-pressure or weight of the air which forced the water into the pump. He concluded that the air-pressure was not great enough to make the water go higher than thirty-two feet. He turned this problem over to Torricelli. Torricelli like Galileo believed that the air-pressure was responsible for raising the water. How could he prove it?

The popular belief of the time was that Nature caused the water to rise in the pump because Nature disliked a *vacuum* (or empty space). This belief did not explain why the water would not rise higher than thirty-two feet although there was still a vacuum above it. Torricelli reasoned that when the pump created a vacuum it really removed the air from the inside of the tube. This took the weight of the air from the surface of the water at the bottom of the tube. Then the pressure of the air on the surface of the water in the well forced the water into the empty pipe. He thought that the reason the water would rise to a height of thirty-two feet only was that the pressure or weight of the air on the surface of the water in the well just balanced the weight of thirty-two feet of water in the tube. To prove this he devised a plan of using some other liquid which had a different weight from that of water. He reasoned that if a liquid heavier than water were used the air-pressure would not be sufficient to raise it even thirty-two feet. For this purpose he selected mercury, about thirteen times heavier than water.

If mercury were used instead of water it should not be possible to pump it higher than one-thirteenth of thirty-two feet, or about thirty inches. He proved that this was the case by using a glass tube about four feet long. He sealed one end of the tube. He

then filled it with mercury and applying his finger to the open end he thrust the open end into a basin of mercury. When he removed his finger the mercury in the tube instantly sank to a height of thirty inches—even though there was a vacuum or empty space in the tube above it. This proved that it was the air-pressure and not the vacuum which maintained the liquid in the tube (Fig. 180). Torricelli called his apparatus the *barometer* or weight-measure.

If a tube with an area of one square inch at its end were used, then there would be thirty cubic inches of mercury in the tube. This amount of mercury weighs nearly fifteen pounds. Therefore the downward pressure of this mercury on a square inch at the bottom is about fifteen pounds. The downward pressure of the air which holds the mercury in the tube must also equal fifteen pounds per square inch.

Fig. 180.
At sea-level atmospheric pressure maintains the mercury in the tube of about 30 inches.

Mercury is about ten thousand times heavier than air at sea level. Therefore a column of the *same* air would have to be ten thousand times as high as the thirty-inch column of mercury in the tube in order to weigh enough to hold the mercury up. By multiplying thirty inches by ten thousand the height of the air would be found to be about five miles. This, however, cannot be the correct height of the air although fifteen pounds per square inch is the correct pressure. Aviators can fly much higher than five miles and balloons have been sent up over four times as high as that. The air must reach up many times higher than five miles and therefore the air must get thinner as it gets higher.

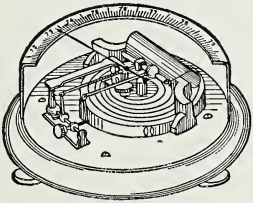
The Height of the Air. At sea level a cubic foot of air weighs one-thirteenth of a pound. A cubic foot of air on the

top of a mountain weighs less than one-thirteenth of a pound. The higher the point at which it is taken the less it will weigh. At the upper limit of the air a cubic foot of atmosphere should weigh practically nothing. The air at sea level is compressed by the weight of air above it. At sea level a cubic foot of air weighs more than a cubic foot higher up because it actually contains more air. We say that the air at sea level is more *dense* than the air above.

Aviators and mountaineers know that the air becomes less dense as they go upwards. They say that the air thins out or becomes *rarefied.* At a height of four miles the air becomes so thin or rarefied that they find it difficult to breathe. Because the air is so rarefied in the higher regions aeroplanes and balloons cannot rise in it. This rarefied air is not dense enough to support them. Since it is impossible to reach the upper limits of the atmosphere by means of balloons we cannot measure the height of the air directly. Is there any other way in which it can be done? You learned when you were studying about shooting stars that they were really small particles of matter. In falling to the earth these particles became heated to incandescence, or glowing, when they entered our atmosphere. The fact that meteors become visible only when they are heated by friction against the air gave scientists a clue as to the probable height of the atmosphere. If the height at which a meteor begins to glow could be measured it would indicate the height of the air. Observations of the heights at which they first become visible shows that the atmosphere extends to a height of at least one hundred and twenty miles. Some observers think that the air, in a very rarefied form, might extend to a height of over two hundred miles.

Air-Pressure and Altitude. The change in air-pressure as one goes upwards is used to determine height or altitude. The change in the pressure is found by using a barometer such as the one Torricelli invented. A French scientist named Pascal discovered that the height of the mercury becomes about one inch less when the barometer is taken up one thousand feet. If

it is taken up another thousand feet the height drops a little less than an inch. For each thousand feet after that the amount of drop of the mercury is a little less each time. By placing a suitable chart on the barometer one can tell at a glance how high he is. Balloons and aeroplanes carry *altimeters*, which are barometers with a chart attached to them to show the height. An altimeter, however, is not usually like Torricelli's barometer but is a very delicate machine which responds to changes in air-pressure. The amount of air-pressure is shown on a dial much like a watch face. The important part of the apparatus is a thin, sealed metal box from which part of the air has been removed.



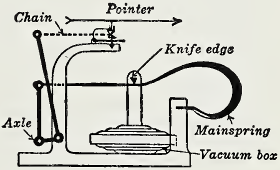


Fig. 181.—(Left) Aneroid Barometer (Right) Diagram to Show How a Slight Bulge of the Metal Box Moves the Pointer

If the air-pressure increases the box bulges in. If the air-pressure gets less a strong spring pulls the bulge out. A pointer attached to the box tells how much the pressure changes (Fig. 181). This type of barometer is called an *aneroid* barometer. It does not contain any liquid and hence it is called aneroid which means having no liquid.

Air-Pressure on All Surfaces. Torricelli proved that the air-pressure at sea level amounted to about fifteen pounds each square inch of surface. It was very difficult at that time to convince people that this was true. If you multiply fifteen by one hundred and forty-four you will see the pressure on a square foot is over a ton. Since this pressure is so great you may well wonder how such an object as a tin can supports all the weight

of air-pressure on its sides. The reason that it does not collapse is that the air-pressure is inside the can as well as outside. The pressure inside the tin just balances the pressure outside it. If the pressure were removed from the inside then the air-pressure would crush the can. You can prove this for yourself.

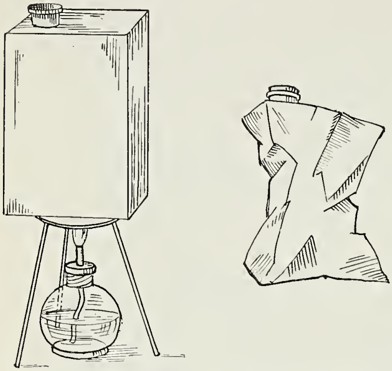


Fig. 182.—The Effect of Air Pressure

PROBLEM

To demonstrate that the air-pressure on the outside of an oil can is great enough to crush it.

Plan. The air can be driven out of the tin can by filling it with steam. If the can be then sealed and cooled the steam will condense into water and leave a vacuum, or empty space, inside the can. There will then be no air-pressure on the inside of the tin to balance the air-pressure on the outside.

Apparatus. An oil can which has a screw cap by which it can be tightly sealed. A bunsen burner and some water.

Method. Put about one-half inch of water in the can. Set the can over a bunsen flame. Remove the cap and allow the water in the tin to boil for several minutes until the can is completely filled with steam. Remove the can and screw on the cap tightly. Allow the can to cool.

Observations. 1. Is the can crushed as it cools? 2. Why did not the steam protect the can from being crushed?

Conclusion. 1. Was there air inside the can while it was being crushed? 2. Does air exert a pressure?

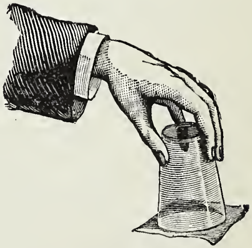


Fig. 183.

Fill a tumbler to the brim with water. Place a piece of stiff paper over the tumbler and invert as shown. Can you explain why the water stays in the tumbler?

This experiment will give you some idea of how great air-pressure is. If it were not for the air inside of our houses they would not be able to withstand the pressure outside. They would be flattened to the earth. The air-pressure on the page of the book you are reading is about a quarter of a ton. How, then, are you able to turn the page with ease? The reason is that the air-pressure upwards under the page is equal to the air-pressure downwards on top of the page. Therefore you have only the weight of the page to turn. If it were possible to prevent the air from getting under the page you would not be able to turn it. Have you noticed the little rubber discs which shop-keepers sometimes use to stick on their windows to hold show cards? They are moistened and pressed against the glass to expel the air. The moisture seals the edges and so the air-pressure holds them in place (see Fig. 183).

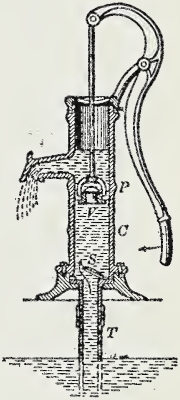


Fig. 184.

This diagram illustrates the parts of a lift-pump. T is the intake tube from the well, S the intake valve, C is the cylinder of the pump, P is the plunger which is forced up and down by means of the handle. In the plunger is the outlet valve V.

Using Air-Pressure. Air-pressure is one of man's useful servants. Long before Torricelli had proved the true cause of the action of a pump in raising water, men had used air-pressure for this purpose without being aware of it. They had used glass tubes or straws through which they drank liquids. They did not know, however, that it was really the air-pressure which forced the liquid up the tubes into the vacuum which they made by sucking. Figures 184 and 185 show how the so-called "suction pump" operates. Study the diagram. What causes the valves to open and close at the proper time? When it is necessary to pump water higher than thirty-two feet a force

pump must be used. Figure 186 is a diagram of a model force pump. Why can such a pump be used to force water to great heights? Figure 187 shows how a liquid can be transferred from one vessel to another by using a tube. Such an arrangement is called a *siphon.* A siphon must be started by first filling the tube with the liquid. An end of the tube is placed in each vessel. The level of the liquid in the vessel to be emptied must be higher than the level of the liquid in the vessel to be filled. The liquid will then flow from one vessel to the other. Notice that it flows upwards from the first vessel. Air-pressure causes it to do so. Can you explain this?

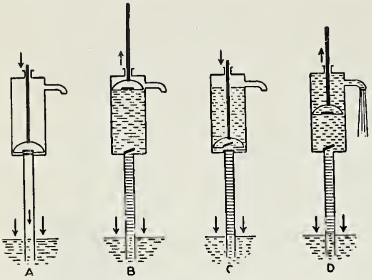


Fig. 185.
By a study of these four diagrams you will understand how atmospheric pressure is used to raise water in a lift-pump.

Since Torricelli's time inventors have put air-pressure to a great many uses. The aeroplane (Fig. 189) is a modern application of the principles of air-pressure. Without air-pressure a machine heavier than air would be unable to fly. In order to stay in the air an aeroplane must keep

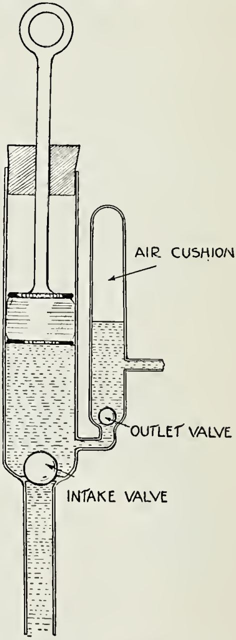


Fig. 186.—A Model Force Pump
What is the purpose of the air cushion?

moving forward. The wings are tilted. As it moves the air-pressure under the wings increases and the air-pressure on top grows less (Fig. 188). The difference in pressure so caused lifts the aeroplane. The newer aeroplanes have carefully designed wings. To increase the difference in pressure you will notice in the diagram that the wings are curved. The arrows in the diagram will show you how the curves of the wings help to increase the difference in pressure. The curves cause the air to pile up on the under side of the wings, while they make a partial vacuum on the upper side.

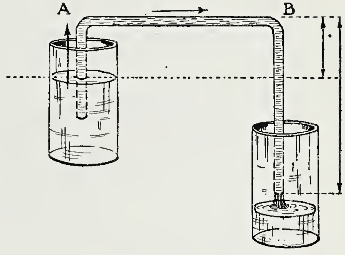


Fig. 187.—A Siphon

The weight of water in arm B is greater than the weight of water in arm A. Therefore the downward pressure in arm B is greater than the downward pressure in arm A. Can you explain why under the circumstances the air pressure causes the liquid to flow in the direction of the arrows?

Air-pressure causes balloons to rise. A balloon is filled with a gas which is lighter than air. A balloon will float upwards only a certain distance because as it goes up the air becomes lighter and the air-pressure becomes less.

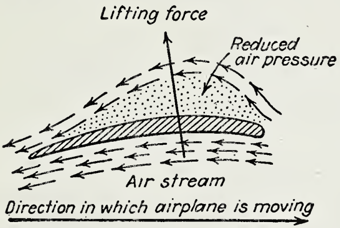
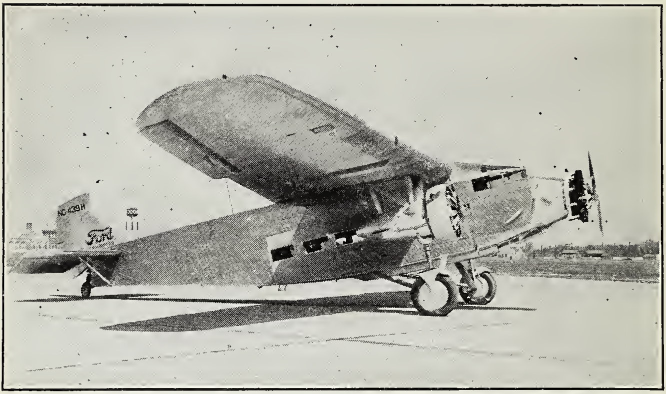


Fig. 188.—How Air is Crowded underneath the Wing of an Aeroplane

Compressed Air Can Do Work. Men have learned that air can be compressed into very small space. When it is compressed it is elastic. You will realize this the next time you kick a football. The football bounces as though it were filled with rubber. You might be interested in seeing how much

air can be compressed into a football. By filling a bottle with water and turning it upside down in a pneumatic trough you can



Courtesy Ford Motor Company

Fig. 189.—A Modern Trimotor Aeroplane

collect the air as it escapes from the football. You may have to attach an extra length of rubber hose to the football bladder in order to lead the air into the bottle.

By means of powerful pumps air is compressed into strong steel

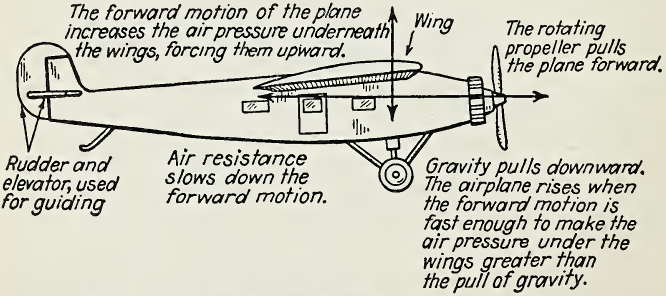


Fig. 190.—The Forces That Act on an Aeroplane

tanks. This compressed air is used to operate rock drills, compressed-air hammers and other compressed engines. It is more convenient to use compressed air than steam for these purposes because it is not hot like steam. Moreover, it can be conveyed long distances through pipes without losing pressure as steam does. Trains are stopped by means of compressed-air brakes on the cars. All devices that use compressed-air are called *pneumatic.* You have heard bicycle tires spoken of as pneumatic tires.

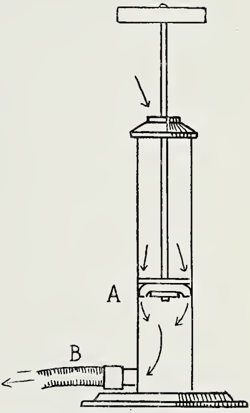


Fig. 191.—A Tire Pump

This is a device for compressing air. When the piston is raised a vacuum is created below the piston. Atmospheric pressure forces air downwards between the leather intake valve A and the sides of the cylinder to fill the vacuum. When the piston is forced downward the intake valve is closed because the air is compressed and the compressed air forces the cupped leather valve against the sides of the cylindes. The compressed air is forced through the tube B into the tire. The valve in the tire prevents the air from returning when the piston is again raised.

Guide Words

air-pressure	dense
vacuum	aneroid
barometer	elastic
compressed air	atmosphere
altitude	decreases
valve	Galileo
gas	mercury
increase	rarefied
crushed	friction
Torricelli	pump
pneumatic	siphon
sea level	substance

Signpost Sentences

1. Air is an invisible ....
2. Air is a .... because it occupies space and has weight.
3. The .... is an ocean of air completely surrounding the earth.
4. A cubic foot of air weighs about one-thirteenth of a pound at ....
5. .... is caused by the weight of the air.
6. The .... is an instrument for measuring air-pressure.
7. A .... lifts water because of air-pressure.
8. .... at sea level is about fifteen pounds per square inch.

9. The atmosphere becomes .... or less dense as one goes upwards.

10. The .... is held in a barometer by the pressure of the air.

11. As the barometer is carried upward the level of the mercury in it lowers; this shows that the air pressure .... as it goes upwards.

12. Although the pressure on the outside of a tin can is enormous the can is not .... because there is an equal pressure on the inside of it.

13. Compressed air is a useful servant; it operates many .... devices.

Questions on the Chapter

1. How would you demonstrate:
   (a) That air occupies space?
   (b) That air has weight?
2. How would you find the weight of air?
3. How do you know that air is a real substance?
4. Describe how to make a mercury barometer.
5. What is a vacuum?
6. Why does air-pressure maintain water at a height of thirty-two feet in a tube while it will hold mercury only to a height of thirty inches?
7. (a) Explain why you can draw lemonade through a straw by suction. (b) The straw sometimes collapses when a pip gets caught on the end of it. Why?
8. Name three devices which use the pressure of the air to operate them.
9. Draw a diagram of a lift pump. Explain how it operates.
10. Why can a barometer be used as an altimeter to measure height?
11. What is the approximate height of the atmosphere?
12. Why is the air at sea level more dense than the air higher up?
13. Name three devices which use compressed air.
14. Why cannot a balloon reach the upper limit of the atmosphere?
15. How is air-pressure used to support an aeroplane?

Special Problems and Practical Applications

1. Explain how a bicycle-pump works.
2. Read the story of the life of Torricelli and tell it to the class.
3. Visit a gasolene station and ask the attendant to explain how the air compressor works.
4. If the gasolene station is equipped with a pneumatic auto-lift, learn how it works and report to the class.
5. In the encyclopaedia read the account of the air-brakes and also the story of George Westinghouse.
6. Calculate the pressure of the air on top of your desk.
7. Hold a flat piece of glass on the surface of a dish of water and try to lift the glass quickly. Account for what happens.

HOME PROJECTS

1. Construct a lift pump. Use pieces of board to make your tube and pieces of rubber for your valves.
2. Make a model aeroplane.

Fig. 192.—Some Applications of Air-Pressure
Can you explain how air-pressure is used in each of the above?

CHAPTER XIX

WINDS AND WEATHER

Can you answer these questions?

1. Why does the weather change?
2. Does the weather change at the new moon?
3. Why does the wind blow?
4. How can the weather be forecast?
5. Why does hail sometimes fall during a hot day in summer?
6. Why does the barometer "fall" when a storm is approaching?

When the Air Moves. You have learned that you could not live without air. You also know that a fire will not burn without it, and you have discovered what a useful servant air-pressure can be. Now you will see how air affects the weather.

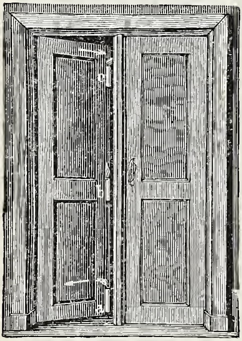


Fig. 193.
The candle flames show the direction of the air currents.

Wind is moving air. On a hot day in summer you have welcomed the cool breeze which brought you relief from the heat. Perhaps later on the same hot day you have been thrilled by a thunderstorm which was followed by a gust of wind. In the winter you have kept close to the fire to avoid the cold which the north winds blew into the house through every crack and cranny. In the springtime you have enjoyed the warm, south breezes which melted the snow. From where did these winds come? What causes the air to move?

Have you ever heard one of your elders say, "Close the door please. There is a draught." You may have been puzzled by such a request, when at the time the outside air seemed perfectly still. There was no wind to cause a draught. If you can discover what causes a draught of air in the house you may learn at the same time what causes the wind to blow.

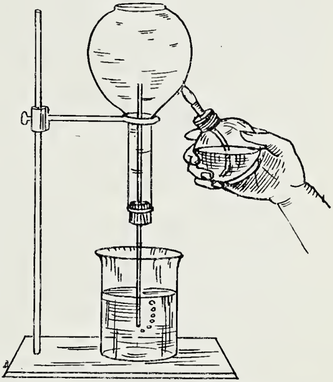


Fig. 194.—A Method of Demonstrating That Air Expands When Heated

When the door of a warm room is opened, a draught of cool air enters the room. If one stands upon a chair in the doorway he will notice also a draught of warm air leaving the room at the top of the doorway. A lighted candle held first in the doorway near the floor and then near the top of the doorway will show the direction of these two draughts. Cool air blows into the warm room when the door is opened. The cool air forces the warm air out of the room. The warm air escapes at the top of the doorway. What causes the warm air to rise? The answer to that question will help in finding the cause of draughts.

Problem

To discover why warm air rises.

Plan. An object which is lighter than water will rise to the surface when it is placed in water. Substances which are lighter than air will float upwards. Balloons are filled with gases which are lighter than air. Since warm air rises to the top of a room one might think it probable that warm air is lighter than cold air. This will be difficult to show directly but if it can be shown that a measured volume of air will expand or occupy more space when it is heated, it will be clear that warm air is lighter than cold air. For example: a cubic foot of cold air weighs one-thirteenth of a pound. If, when it is heated, the volume becomes more than a cubic foot, then a cubic foot of the expanded air must weigh less

than one-thirteenth of a pound. The problem is to show that air does expand when it is heated.

Apparatus. A bottle, a dish of water, a bunsen burner, a one-holed stopper, a piece of glass tubing.

Method. Put the glass tube in the stopper and insert the stopper in the neck of the bottle. Turn the bottle upside down and put the end of the glass tube in the dish of water as shown (Fig. 194). Heat the bottle gently with a bunsen flame and later allow it to cool.

Observations. 1. Do any bubbles escape from the bottle as it is heated? 2. Does any water enter the bottle as it cools? 3. While the bottle is hot does any water enter it?

Conclusion. 1. Does heat cause air to expand? 2. Does warm air occupy more space than cold air? 3. Is warm air lighter than cold air?

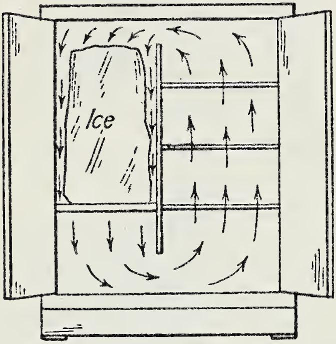


Fig. 195.—Cross-Sectional Diagram of an Ice Refrigerator

Why does the air circulate in the manner shown by the arrows? Is there any particular reason for placing the ice in the upper part of the box?

Heat Causes the Winds. This experiment proves that heat causes air to expand. When it expands it becomes lighter. Lighter air is forced upwards by the cold, heavier air in the same way that a substance lighter than water is forced to the surface of water. The first balloons made were hot-air balloons. They were large, paper bags filled with hot air. When they were released they floated upwards because the hot air in them was lighter than the surrounding air.

When there is a hot stove in a room the air around the stove becomes heated and expanded. The expanded air is lighter than the air farther from the stove. The cooler, heavier air moves towards the stove beneath the warm air. As it does this it pushes the warm air upwards. In this way a draught is started. This draught carries the warm air to all parts of the room. When the door of the warmed room is opened the heavy, cold air flows in and pushes the warm air up and out of the open doorway.

The winds are caused similarly by the unequal heating of the air on the surface of the earth. The heat from the sun is greater in some places than in others. This causes winds in the air just as the hot stove caused a draught in the room.

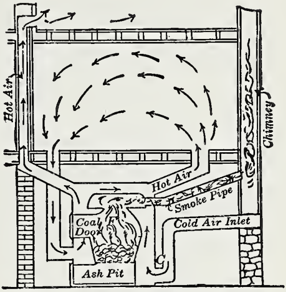


Fig. 196.—Hot Air System of Heating

Winds of the World. The equatorial regions of the earth are warmer than other regions. The air above these regions is made lighter by the heat. This causes winds to blow steadily towards the equator (Fig. 199). These winds are named the "Trade Winds". The Trade Winds do not blow directly towards the equator. Because of the daily rotation of the earth they are turned towards the west. As the Trade Winds blow they force the warmed lighter air upwards.

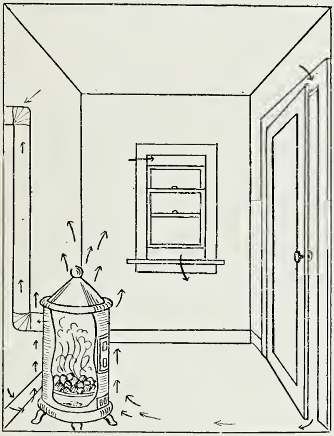


Fig. 197.—How a Fire Helps to Ventilate a Room

What becomes of the warm air which is forced upwards by the Trade Winds? It is clear that the air cannot stay "up" or else the supply of air would soon vanish. As this air moves upwards it becomes cooled. When it becomes cooled it contracts and thus becomes heavier. The cooled, heavy air falls. But it does not fall back on the warm area. The continually rising air forces it to the north and to the south. Let us follow the wind which blows to the

Northern Hemisphere. It falls to the earth between the latitudes of 30 degrees N. and 40 degrees N. As it falls it causes other winds to blow since when it falls it pushes the lower air aside. Some of the winds caused in this way blow towards the equator and join the Trade Winds. Others of them blow towards the north. These are named the Westerlies. The Westerlies do not blow directly towards the north. They are deflected or turned by the rotation of the earth just as the Trade Winds are turned. The Westerlies blow towards the north-east.

Figures 199 and 200 illustrate the principal winds of the world.

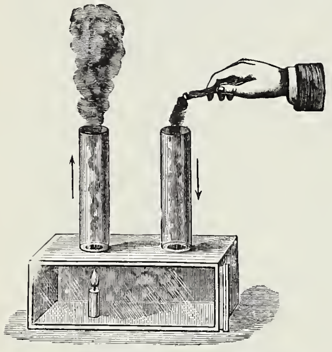


Fig. 198.—Demonstrating How Heat Causes Air Currents
The smoke indicates the direction of the current.

Sea Breezes and Land Breezes. The winds which are marked on the diagrams do not blow constantly. The diagrams show only the directions in which the winds usually blow. Certain conditions cause the winds to blow in other directions. If you live near the ocean you have noticed that during the day a sea breeze blows towards the land and that at night a land breeze usually blows towards the sea. These land breezes and sea breezes are the result of the differences in temperature between the land and the ocean. During the day the heat from the sun causes the land to become warm quite rapidly while the temperature of the water rises slowly. The air above the land becomes warmer and lighter than the air above the water. The heavier air over the sea moves landward to displace the lighter air over the land. A sea breeze results. On the other hand, at night the land cools rapidly while the temperature

drops but little over the sea. A land breeze then blows towards the ocean (Fig. 201).

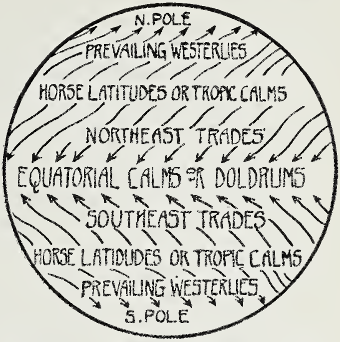


Fig. 199.—The Directions in Which the Principal Winds of the Earth Blow

Just as local land and sea breezes are caused by differences in temperature near the coast so continent-wide winds are caused by the difference in the temperature of the air over large bodies of land and the temperature of the air over large bodies of water. During the summer the land areas become very warm. The air over these land areas then becomes much lighter than the air over the oceans. As a result the prevailing or usual winds of summer are towards the large land areas and as a general rule the prevailing winter winds are towards the oceans.

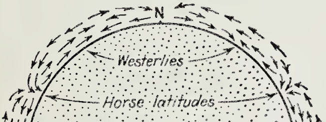


Fig. 200.—The Air Currents Which Cause the Winds

Notice the air in the upper atmosphere moves in a direction opposite to the air on the surface of the Earth.

Cyclones. Whenever the air becomes light over an area the air-pressure over that area becomes lessened. This area is then called a *low-pressure area.* The colder air above the regions which surround a low-pressure area causes the air pressure of these colder regions to be greater. These latter regions are called *high-pressure areas.* The winds always blow

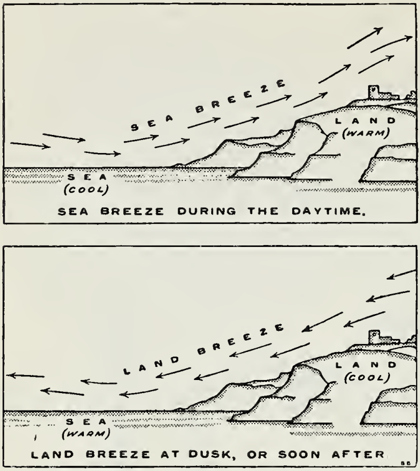


Fig. 201.—Land and Sea Breezes

from high-pressure areas towards the centre of a low-pressure area. In the northern hemisphere all winds turn to the right of the direction in which they are blowing because of the rotation of the earth. This turning towards the right by winds which blow towards low-pressure areas causes the air there to whirl in great *cyclones* or circles (Fig. 202). These cyclones whirl in a *counter-clockwise* direction, i.e., in a direction opposite to the way the hands of a clock turn.[1] In the southern hemisphere the cyclones whirl in a clockwise direction. A cyclone is usually several hundred miles wide. Winds which blow away from high-pressure areas are called *anti-cyclones.*

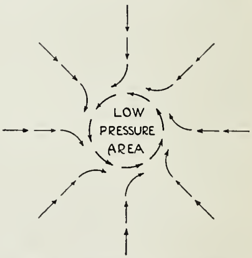


Fig. 202.—Cyclones

Winds blowing toward a low-pressure area cause a circular movement of the air in the low-pressure area.

The Weather Parade. Cyclones and anti-cyclones move across the land (Fig. 206). In North America they usually move from the west to the east in the path of the Westerlies. They enter from the Pacific

[1] A circular motion moving in the direction in which the hands of a clock move is said to be clockwise; if moving in the opposite direction it is said to be counter-clockwise.

Ocean somewhere in the region of the Province of British Columbia and the State of Washington. They pass across the southern part of Canada and the northern portion of the United States. As a rule they leave by way of the St. Lawrence Valley. Cyclones and anti-cyclones follow each other in turn across the continent. This has an effect upon the weather conditions of the country over which they pass (Fig. 203).

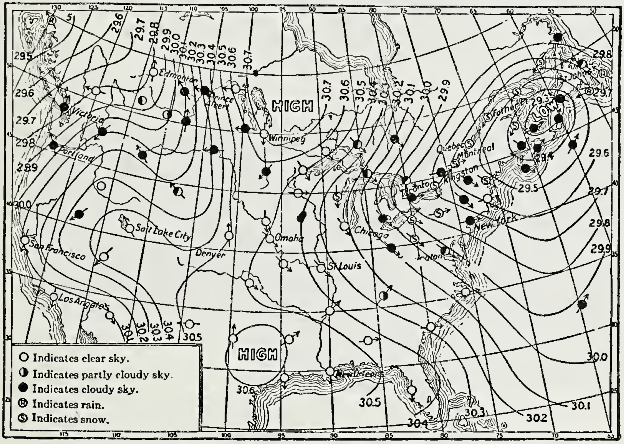


Fig. 203.—A Weather Map

Why the Weather Changes. Warm air usually contains much water vapour. Water vapour is lighter than air. When water vapour is mixed with it the air is made lighter. The water vapour in a cyclone thus helps to make the air pressure still lower. When the winds which blow into the cyclone force the light air upwards to the colder atmosphere this water vapour condenses on the dust particles in the air. The tiny droplets so formed float about as clouds. With further cooling the droplets grow larger as more water vapour condenses on them until in time they become so large that they fall to the ground as rain.

When the air is very cold the water vapour does not form into droplets as it condenses but it slowly forms snowflakes. Snowflakes are composed of tiny ice-crystals (Fig. 204). In each snowflake the ice-crystals form a beautiful pattern. You should examine some snowflakes with a lens. If you catch them on a piece of black cloth you can see the patterns more easily. Snowflakes when melted become water again.

When there is an extremely low pressure over any area violent winds result. These winds force the light air of the low pressure area to rise so rapidly that the droplets of water which condense are carried high enough to reach freezing temperatures. They

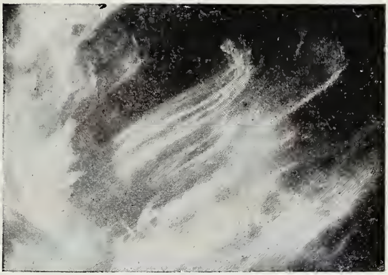
Fig. 204.—Snowflakes

form small pellets of ice. As these pellets fall more vapour condenses upon them. The rapidly rising current of air drives the moist pellets upwards once more and they freeze again. They may fall and be blown back several times. Each time they grow larger until they become so large that the rising air can no longer hold them and they fall to the ground as hailstones. If you break a hailstone open you will see the layers of ice of which it is made.

Clouds. The low lying clouds often seen at sunset are called *stratus* clouds. The higher billowy clouds are called *cumulus* clouds. Cumulus clouds occur in a blue sky. When they gradually disappear they indicate fair weather. When they develop into darker clouds, called *cumulo-nimbus,* they indicate an approaching storm. They occur from a height of about three-quarters of a mile

to about three miles. From about three miles up the *alto-cumulus* clouds appear. They give the sky a dappled appearance. The highest whisp-like *cirrus* clouds appear from six to seven miles high. Since the temperature is below freezing at that height these clouds are composed of tiny ice-crystals (Fig. 204).

Forecasting the Weather. Because weather plays such an important part in our daily affairs the government has established bureaux or stations both for studying the weather and for forecasting weather conditions. You will be able to understand how this is done since you know the causes and movements of cyclones. It will help you also if you recall the other facts which you have learned about air conditions. You have learned that: 1. low-pressure areas cause cyclones to form; 2. high-



"MARES TAILS"—CIRRUS

CUMULUS

CUMULO-NIMBUS

(From photographs by Mr. G. A. Clarke, Aberdeen)

Fig. 205.—Types of Clouds

pressure areas cause anti-cyclones; 3. the air in a cyclone usually contains a great deal of water vapour; 4. winds blow from high-pressure areas to low-pressure areas; 5. cyclones and anti-cyclones move eastward across Canada. A knowledge of these facts has made it possible for the weather bureau to forecast, or predict, the weather in any place for at least twenty-four hours in advance.

For example: If you are in a low-pressure area, you may expect cool winds to blow towards you. These cool winds will cause the moisture-laden air to rise and you may expect cloudy weather, which will be followed by rain or snow. If, on the other hand, you are in a high-pressure area you may expect

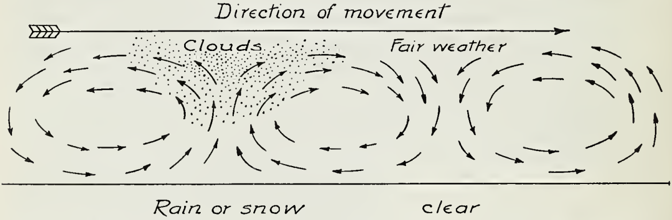


Fig. 206.—How Cyclones and Anti-Cyclones Follow Each Other

continued fine weather since the winds will be blowing away from you.

Weather Instruments. You can determine the presence of low- or high-pressure areas by means of a barometer. At sea level the normal or usual height of the mercury is 29.9 inches. If it is less than that the air pressure is low. If it is more, the air pressure is high.

The *humidity,* or the amount of water vapour in the air, plays an important part in determining weather. Water vapour in the air is the source of rain, snow and hail. In a low pressure area, when the humidity is high, you can be almost certain that it will soon rain or snow. The amount of humidity is determined by using a *hygrometer.*

In order to know how fast the cyclones are travelling across the country the weather bureau maintains *meteorological stations*, or weather observatories, in different parts of the country. Here daily records are made of: 1. the air pressure; 2. the humidity; 3. temperature; 4. direction of winds; 5. speed of winds; 6. cloud formations. This information is telegraphed to the weather bureaux in the principal cities. Daily weather charts (Fig. 202) are made showing all these facts from each of the observatories. The positions of the cyclones, their speed and the direction in which they are moving are then determined. When these facts are known the probable weather conditions can be foretold.

Courtesy Taylor Instrument Company of Canada, Limited

Fig. 207.

Note the funnel shape of this tornado. Note the black spot at its base indicating flying objects. It revolves at a terrific rate of speed. It also moves across country at a rapid rate.

Of course the predictions are general in character and usually apply to large areas. There are many local weather facts which apply to a particular locality that do not affect the weather over a large area. In mountainous country the local weather conditions are often different from the forecast of the weather bureau. For this reason the local signs of weather are worth noting. The colour of distant hills and the clearness with which they can be seen sometimes give an indication of the coming weather. No doubt you have heard of many weather signs such as these: "A red sunset means a clear

tomorrow." "Rainbow at night, sailor's delight; rainbow at morning, sailors take warning." "When distant hills are sharp and clear, stormy weather is quite near", and many others.

Tornadoes. Extremely violent wind-storms are called hurricanes or tornadoes. They are caused by differences in air-pressure greater than usual. Very low pressures are produced when the air becomes excessively hot and when there is an unusual amount of water vapour in it. The colder air from the surrounding high-pressure regions moves towards the low-pressure area with such speed and force that a whirlwind is caused as the air at the centre of the low-pressure area rises. The air whirls so rapidly that a *vortex* is formed. You have seen a vortex of whirling water as it went down a drain. The vortex of a tornado is upwards instead of downwards. The funnel-shaped vortex of a tornado can be seen easily because of the water vapour which condenses in it and forms a dark cloud at the centre. The force of the wind in the vortex of the tornado is very great. It is thought that the speed of the wind sometimes reaches five hundred miles per hour. Trees are often uprooted and are broken, houses are destroyed and very heavy objects like pianos and automobiles have been lifted and tossed about by a passing tornado. Fortunately the paths of tornadoes are seldom more than twenty-five miles in length nor more than a few hundred feet in width.

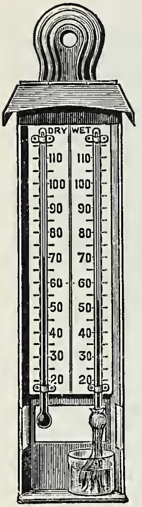


Fig. 208. Wet- and Dry-Bulb Hygrometer

Humidity. Besides being useful as an indication of the weather, knowledge of the humidity of the air is of importance for other purposes. When the humidity is low the air is "dry." Water then evaporates into the air quickly. Leaves and twigs dry out. Forest fires start easily and burn fiercely in the dried woods. Forest rangers must be alert to prevent forest fires when

the humidity is low. They need hygrometers to measure humidity.

There are several types of hygrometers. A type of hygrometer in common use is the "wet- and dry-bulb" hygrometer. The principle which governs its use is the fact that, when water evaporates, heat is absorbed—or used up. On a very dry day the humidity is low and water evaporates quickly. With the increased evaporation more heat is used up. When the humidity is high there is little evaporation and little heat is absorbed. This wet- and dry-bulb hygrometer consists of two thermometers. The bulb of one of the thermometers is kept moist by means of a wick and a dish of water. The bulb of the other is kept dry (Fig. 208). As water evaporates from the wick, heat is absorbed from the wet bulb and this thermometer shows a lower temperature than the dry one. The greater the difference between the temperatures of the two thermometers the more rapidly evaporation is taking place and the drier the air must be. If the two thermometers show the same temperature this fact indicates that no evaporation is taking place from the wet bulb. This means that the air can hold no more water vapour. It is *saturated*. If the air has but one-half the amount of water vapour necessary to make it saturated it is one-half or fifty per cent saturated. The percentage of saturation is called the *relative humidity*. By noting the difference in temperature between the two thermometers and by referring to the chart on the next page (Fig. 209) the relative humidity of the air can be determined.

Guide Words

thunderstorm	draught	equatorial regions
Trade Winds	Westerlies	sea breeze
land breeze	prevailing wind	cyclone
anti-cyclone	humidity	hygrometer
low-pressure area	barometer	northern hemisphere
high-pressure area	weather map	tornadoes
temperature	wind	expands
hurricanes	warm air	pressure
southern hemisphere	cold air	

TABLE GIVING RELATIVE HUMIDITY

Reading of Dry Thermometer (Fahr.)	Reading of Wet Thermometer (Fahr.) 70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53
80	61	57	54	51	47	44	41	38										
79	63	60	57	54	50	47	44	41	37									
78	67	64	60	57	53	50	46	43	40	37								
77	71	67	63	60	56	52	49	46	42	39	36							
76	74	70	67	63	59	55	52	48	45	42	38	35						
75	78	74	70	66	63	59	55	51	48	44	40	38	34					
74	82	78	74	70	66	62	58	54	51	47	43	40	37	34				
73	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33			
72	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32		
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	
70		95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30
69			95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32
68				95	90	85	81	76	72	67	63	59	55	51	47	43	39	35
67					95	90	85	80	76	71	67	62	58	54	50	46	42	38
66						95	90	85	80	76	71	66	62	58	53	49	45	41
65							95	90	85	80	75	70	66	62	57	53	48	44
64								95	90	85	79	75	70	66	61	56	52	48
63									95	90	84	79	74	70	65	60	56	51
62										94	89	84	79	74	69	64	60	55
61											94	89	84	79	74	68	64	59
60												94	89	84	78	73	68	63

Fig. 209.—Table Showing Relative Humidity

To find the relative humidity: (1) Find the temperature recorded on the wet-bulb thermometer, at the top of the chart; (2) Find the temperature recorded on the dry-bulb thermometer at the left of the chart; (3) Trace down the column under the wet-bulb reading to the figure opposite the dry-bulb reading. This figure is the relative humidity. For example, if the wet-bulb thermometer reads 69° (Fahr.) and the dry-bulb thermometer reads 78° (Fahr.), the relative humidity is 64%. For healthful and comfortable living conditions indoors the humidity should always be above 50. With the relative humidity above 50 the temperature need not be above 68° in order to be warm and comfortable. Why?

Signpost Sentences

1. .... is moving air.
2. Draughts and winds are caused by differences in .... of the air.
3. Warm air is lighter than cold air because air .... when it is heated.
4. ...., which is lighter than cold air, rises when heavier, cold air falls beneath it and forces it up.
5. A .... is formed when the air above it becomes lighter.

6. A. .... is formed when the air above it becomes heavier.
7. Winds blow from a high-pressure area to a ....
8. Winds in the .... turn to the right.
9. .... are formed when the air of a low-pressure area is set whirling by the incoming winds.
10. .... refers to the amount of water vapour in the air.
11. In a low-pressure area the .... is usually higher than in the high-pressure areas surrounding it.
12. The .... is used to measure humidity.
13. Cyclones and .... follow each other in succession, across Canada.
14. Violent wind storms such as .... and .... are caused by great differences in air pressure in adjoining localities.

Questions on Chapter XIX

1. How could you show that a draught is blowing out of the top of a doorway while one is blowing in at the bottom?
2. How could you prove that warm air is lighter than cold air?
3. Why is the air near the ceiling of a room warmer than the air near the floor?
4. What causes warm air to rise?
5. Why does a hot air balloon rise?
6. Why does the air circulate in a room where there is a hot stove?
7. In low latitudes the prevailing winds blow towards the equator. Why?
8. What becomes of the warm air which rises along the equator?
9. At the beach it was noticed that during the afternoon the breeze blew from the water while in the evening it blew from the land. Can you account for this?
10. Why does the barometer rise on some days and fall during others?
11. How could you discover whether you were in a cyclone or an anti-cyclone?
12. If you are in a low-pressure area you may expect stormy weather. Why?
13. How does the weather bureau know when a cyclone is approaching?
14. Why is the vortex of a tornado visible?
15. By knowing the humidity, forest rangers can tell when forest fires are most likely to occur. What has humidity to do with forest fires?
16. On looking at a wet- and dry-bulb hygrometer it was noticed that the temperature of the wet bulb was much lower than that of the dry bulb. What does this tell you about the humidity of the air?

Special Problems and Practical Applications

1. Why do the Trade Winds turn toward the west while the Westerlies turn towards the east?
2. In observing a barometer it was noticed that the pointer indicated "fair". Twelve hours later the pointer had moved to "change" and the next day it had moved towards "storm". What change had occurred in the air conditions? A trained observer would be able to tell from

these changes whether a cyclone was approaching the locality or leaving it. Can you tell?

3. Why does the air from the hot-air furnace in the basement rise through the pipes to all parts of the house? (Fig. 196).

4. Why should the bedroom window be open both at the top and at the bottom?

5. Almanacs are published which forecast the weather for a year in advance. Are these forecasts reliable?

6. Explain why hailstones are built up in layers.

7. Tell why the weather forecast is of importance to: (*a*) aviators; (*b*) fruit growers; (*c*) farmers; (*d*) meat and produce shippers; (*e*) mariners.

8. Why is the block of ice usually placed at the top of an ice chest? (Fig. 195).

9. On a cork place a drop of water. Place a watch glass on top of the water. Fill the watch glass with ether. Fan briskly. What happens to the ether? The drop of water becomes ice. Can you explain why?

Home Projects

1. Examine your furnace at home. If it be a hot-air furnace see where the cold air enters it. Why does the heated air reach the upper parts of the house?

2. (*a*) There are several different types of hygrometers. You may wish to make one for yourself. If you can secure two thermometers you can make a wet- and dry-bulb hygrometer similar to the one described in the text.

(*b*) Another type of hygrometer can be made from a long piece of rope. On humid days the rope will absorb moisture from the air and will shrink. When the humidity of the air is low the rope dries out and will stretch. To observe this stretching and shrinking tie a weight on the end of a long rope and then hang the rope from a high window so that the weighted end is a few inches from the ground. With a piece of chalk mark on the wall the height that the weight is above the ground. Notice the change in the length of the rope from day to day.

3. Keep a weather chart for a year. You can do so by ruling a sheet of paper in columns. These columns should show the date, temperature, sky condition, direction of the wind, speed of the wind, probable weather tomorrow.

UNIT IX

ELECTRICITY

CHAPTER XX

ELECTRICITY

Can you answer these questions?

1. When was electricity discovered?
2. What causes lightning?
3. Why are electric sparks sometimes seen when a cat is stroked?
4. What is an electric current?
5. Why are the handles of electricians' tools covered with rubber?
6. Why do electric lights have two wires to carry the current to them?
7. Can electricity be used to send messages?
8. How is water-power changed into electric power?
9. Can electric currents be made from chemicals?
10. Why does an electric iron get hot when the current is turned on?

The Secret of the Thunder-storm. Sometime during the summer you must have watched a thunder-storm. At first, you saw dark thunder-clouds gather. Then you saw a flash of lightning which was followed by a thunder-clap. As the lightning struck nearer and nearer the loud report of the thunder followed more closely after each flash. As you watched the storm, no doubt, you wondered what mighty forces could create such a spectacle. What is a thunderbolt? What gives it the power to

shatter trees and to wreck houses and kill people when it strikes them?

It was to answer these questions that an American scientist, Benjamin Franklin, conducted his famous experiment with lightning. Franklin had thought that an electric spark and lightning were the same and that the snap of an electric discharge was the same as the thunder-clap. He proved this theory by doing an experiment in the scientific method as follows:

Caution.—Pupils are warned not to attempt this experiment as it is dangerous.

PROBLEM

His problem was to prove that lightning and an electric discharge were the same.

Plan. He planned to prove his theory by sending a kite into a thunder-cloud. He expected that some of the electricity would flow along the twine of the kite from the cloud to the earth.

Apparatus. With this in view he made a kite by stretching a silken handkerchief over a small cross of cedar. To the middle of the cross he fastened an upright pointed wire. He then attached the tail and the twine and was ready for the experiment.

Method. In June of the year 1752, he flew the kite into a thunder-cloud. When the kite was well up he tied a silk ribbon to the end of the twine. This was to prevent the electricity from passing into his hand and thence to the ground. To the twine, where it joined the ribbon, he tied a key. In order to keep the ribbon dry he stood within a doorway. He was careful to see that the twine did not touch the doorway.

Observation. Franklin soon noticed that the fibres on the twine stood out as they do when charged electrically. He also noticed that a spark jumped from the key to his finger.

Conclusion. By means of instruments Franklin was able to show that sparks which he obtained from the clouds were in every way the same as sparks obtained from electrical discharges. He concluded that thunder-bolts, were huge electric sparks.

The Discovery of Electricity. Electricity has come into general use so recently that you might think it was discovered but a few years ago. Such is not the case. Franklin knew of electricity one hundred and fifty years ago. The first studies of electricity were made much earlier than that. It is said that Thales of Greece knew of electricity as long ago as 600 B.C. He noticed that amber, when rubbed, had the power of attracting

straws and other light objects. We know now that objects which have been electrified have the power of attracting to them such light objects as straws, pith balls and pieces of paper.

The discoveries which led to the modern development of electricity were made by an English scientist, Dr. Gilbert, who lived during the reign of Queen Elizabeth. He learned that many substances when rubbed, had, like amber, the power of attracting light objects to themselves.

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Fig. 210.—Franklin's Experiment With a Kite During a Thunder-Storm

This power of attraction was called *electricity* by Dr. Gilbert after "electron", which was the Greek word for amber. You will remember that it was in amber that this electrical power was first noticed.

You can demonstrate this electrical property of attraction by rubbing a hard-rubber fountain pen on a woollen coat or dress.

Notice that small pieces of paper are attracted to the pen after it has been rubbed.

Electric Charges. An object which has been electrified by rubbing it in this way is said to be *charged* with *electricity*. It was soon discovered that electrically charged bodies had other properties besides that of attracting objects. On a frosty winter's evening, as you stroked the cat you may have noticed a crackling sound. If you had put out the lights you would have seen tiny sparks on the cat's fur. Scientists also noticed that a spark jumps when an electrically charged object is touched with a finger. The sparks produce flashes of light and crackling sounds. Thus they learned that electricity would jump from a charged body. In time they discovered that when a wire is attached to an electrically charged body the unattached end of the wire behaved as though it were charged. It attracted pieces of paper and a spark would jump from it when it was touched. It was evident that the wire conducted or carried away the charge from the charged object.

Conductors of Electricity. By experiments it was found that some substances conduct electricity well, while others conduct it not so well. Those which conduct electricity well were called good *conductors*. Those which do not were called poor conductors. Materials like glass and rubber which do not conduct electricity at all were called *non-conductors*. When two non-conductors are rubbed together an electrical charge is produced upon them. As an example, if silk is rubbed on glass an electrical charge is produced both on the silk and on the glass. Likewise when ebonite (hard rubber) and cat's fur are rubbed together there is a charge produced on each.

When two conductors are rubbed together, electricity is produced by friction in the same way. In this case, however, the electricity passes from the conductors into the hands and then through the body into the ground so that the electricity disappears as fast as it is produced.

How to Study Electric Charges. To demonstrate electric charges a very simple device, the pith-ball electroscope is used. It consists of a small ball made of the light pith of the elder tree. This ball is suspended by a silken thread. You can use such a device in your study of electric charges (Fig. 211).

PROBLEM

To study electric charges.

Plan. Objects of light weight are affected by electric charges. You can study the effects of these charges on a pith ball when the charges cause it to move.

Apparatus and Materials. Ebonite rod, cat's fur, glass rod, a piece of pure silk and a pith ball suspended by a silk thread.

Method. 1. Charge the ebonite rod by rubbing it with cat's fur. Hold the rod near the suspended pith ball. 2. Allow the pith ball to touch the charged ebonite rod and after it has once touched the rod try to make it touch again (Fig. 211). 3. Charge the glass rod by rubbing it with the piece of silk. Hold the charged glass rod near the pith ball. Allow the pith ball to touch the glass rod. Now hold the charged ebonite rod near the pith ball again.

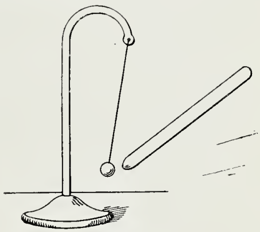


Fig. 211. Apparatus for Studying Electric Charges

Observations. 1. Does the charged ebonite rod have any effect upon the pith ball? 2. What happens to the pith ball after it touches the charged ebonite rod? 3. What effect did the charged glass rod have upon the pith ball? 4. Does the charged glass rod affect the pith ball in the same way that the charged ebonite rod does?

Conclusion. 1. Was the same kind of electric charge produced on both the ebonite rod and the glass rod? 2. When the pith ball touched the ebonite rod did it receive a charge? 3. Do similar charges attract or do they repel each other? 4. Do unlike charges attract or repel each other? 5. Was the charge on the pith ball changed when it touched the glass rod.

As you did this experiment you found that the pith ball was first attracted by the charged ebonite rod. After touching the rod it jumped away again and was now repelled, or pushed away, from the rod instead of being attracted towards it. When the glass rod was rubbed with silk and held near the same pith ball you found that the pith ball was attracted to the glass rod at the same time that it was repelled from the ebonite rod.

When the pith ball touched the glass rod it was then repelled from the glass rod and attracted by the ebonite rod once more.

Two Forms of Elecricity. How can the strange behaviour of the pith ball be explained? It is clear that electricity must exist in two forms. The form which is produced by the friction on glass is called positive (+) electricity. The form which was produced on the ebonite rod by rubbing it with cat's fur is called negative (—) electricity. When the pith ball touched the ebonite rod it became charged with negative electricity from the rod. It was then repelled from the rod. Thus we learn that like charges of electricity repel one another. The pith ball now moves toward the glass rod which is charged positively and we learn that unlike charges of electricity attract one another.

The Nature of Electricity. Within the last thirty years scientific researches or investigations have made it possible to understand more clearly the nature of these electric charges. We now have reasons to believe that substances always contain particles of both positive and negative electricity. When there are equal numbers of positive and negative particles of electricity in a substance the one kind of electricity *neutralizes* or balances the effects of the other kind and so neither kind can be detected in the substance. We say that it carries no electrical charge.

If some of the negative particles of electricity are removed from an object then it will have more positive than negative electricity in it and so it will be "positively charged".

On the other hand, if a substance has received more than its regular number of negative particles of electricity it is "negatively charged". Even a very small charge of negative electricity may contain millions of these particles.

We have also learned that the particles of negative electricity are the only kind of electric particles which will move from one object to another. These particles of negative electricity have been named *electrons*. The particles of positive electricity have been named *protons*. Protons do not move but always remain within a substance.

How Electricity is Produced by Friction. In the light of this knowledge we are now able to understand what happens when the ebonite rod is rubbed with the cat's fur. Electrons are detached or removed from the cat's fur and accumulate on the ebonite rod. The cat's fur which has lost electrons is now positively charged and the ebonite rod which has extra electrons becomes negatively charged. When the pith ball touches the ebonite rod it receives some of these electrons. The pith ball then also becomes negatively charged. Like charges repel. Consequently the pith ball is now repelled from the negatively charged

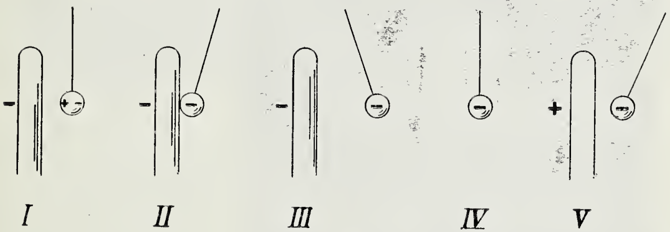


Fig. 212

I. When the ebonite rod is rubbed with fur it becomes charged negatively. II. It attracts the pith ball and the pith ball becomes charged negatively because the positive charge on the pith ball is neutralized. III. The pith ball is then repelled by the charged ebonite rod. IV. The pith ball retains its negative charge. V. It is attracted to a glass rod which has been rubbed with silk and so has been charged positively.

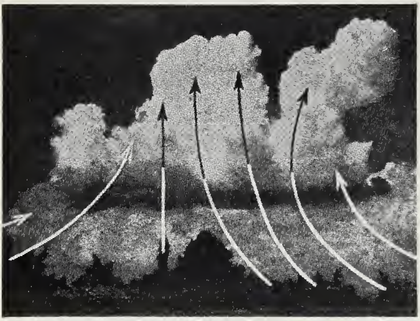
ebonite rod. Can you explain in a like manner what happens when the glass rod is rubbed with silk? Why does the pith ball now move towards the glass rod? Why is it repelled after it has touched the glass rod? (Fig. 212).

The Electric Spark. Electricity which has been produced by friction on non-conductors is called *static* or standing electricity. When electrons are on the surface of an ebonite rod, the rod is said to be charged with static electricity.

Electricity does not always stand still. Since like charges of electricity repel one another, when the surface of an

ebonite rod is charged negatively and so covered with electrons, each electron repels its neighbour. If the charge is very great and the electrons on the surface are numerous the pressure, or *potential,* with which they push away from one another is very great. At such times if you place your finger near the rod the pressure or the electric potential of the charge on the rod will drive electrons from the tip of your finger into your body.

This now leaves a positive charge on the tip of your finger. We say that the positive charge has been *induced* by the negative charge of the rod. Unlike charges attract, consequently the positive charge of the finger attracts the negative charge of the rod. If the charge on the rod is great enough the electrons will jump from the rod to your finger. This is called an electrical *discharge.*



Courtesy Taylor Instrument Company of Canada, Limited

Fig. 213.
Thunder-clouds are produced by a rapidly rising column of humid air.

These electrons travel at such an enormous speed that a flash of light or spark is produced by the friction of their movement through the air. The sound which is produced along with the spark is the result of air-vibrations caused by the sudden expansion and contraction of the heated air.

The *potential,* or pressure, of an electric charge is measured in *volts.* A potential of 25,000 volts is necessary to produce a spark an inch long. Calculate the voltage necessary to produce a spark five inches long. Imagine the amount required to produce a thunderbolt a mile long. You will now understand why a lightning flash is destructive when it strikes.

Courtesy Physician's Pharmacy, Vancouver

Fig. 214.

Lightning is an electrical discharge, from cloud to cloud or between clouds and earth. This picture was obtained by allowing the shutter of the camera to remain open. In this way several successive flashes of lightning were recorded in a single picture.

Electricity Causes Lightning. Now that you know something of electricity you are in a better position to understand lightning. Clouds become charged with electricity before a thunderstorm. Experiments have shown that when drops of water are broken up by moving currents of air the drops lose electrons and become positively charged. The air receives the electrons and so becomes negatively charged. During

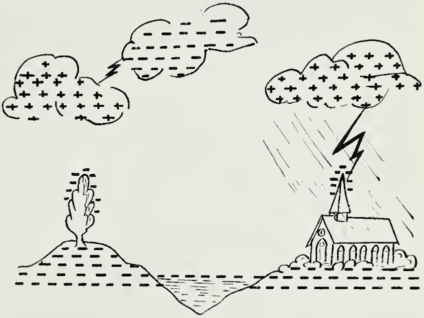


Fig. 215.—Lightning

thunderstorms there is a rapid upward movement of air (Fig. 213). Drops of water in thunderclouds are broken up by the force of this rising air. These drops become positively charged while the air is negatively charged. The lighter drops are carried upwards and receive a negative charge from the air. As a result of this the higher clouds become negatively charged while the lower clouds are positively charged. Let us imagine that a negatively charged cloud drifts over a hill. The negative charge of the cloud will repel negative charges from the substance of the hill top. The hill top now becomes positively charged. Unlike charges attract and if the potential or voltage of the charge on the cloud is great enough there will be an electric discharge to the earth. The sound produced will be heard later than the flash because sound requires time to travel in the air while the light of the flash can be seen almost instantly.

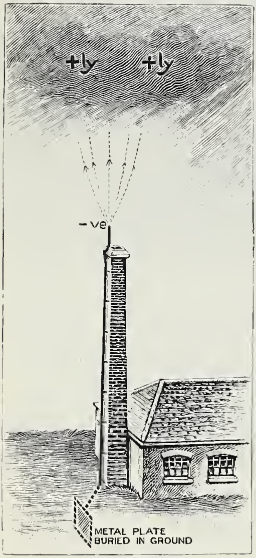


Fig. 216.—Diagram of Lightning Rods

A lightning rod discharges electricity of the opposite kind to that in a cloud, thus tending to neutralize the charge in the cloud.

Lightning Rods. You will now understand why high objects on the earth are more often struck by thunderbolts than other objects. Can they be protected? Benjamin Franklin noticed that electric discharges took place quietly and without sparks from or towards pointed metal objects. He suggested for the protection of buildings against lightning, the use of metal rods pointed at the upper end and connected with the ground at the lower end. The lightning rods conduct the electricity to or from the ground while the

points on them allow the electric charges which have gathered to escape quietly.

You do not need to be afraid of lightning. The possibility of your being struck by lightning is very small indeed. Nevertheless when thunderstorms are close it is not wise to take shelter

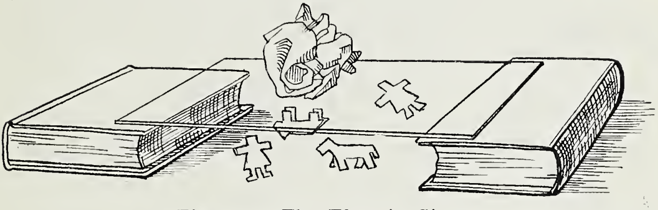


Fig. 217.—The Electric Circus

Can you explain why the paper dolls jump up and down when the glass plate is rubbed with silk?

under tall trees, particularly under those which are on hill tops. It is advisable also not to touch or stand near metal water pipes during thunderstorms.

Current Electricity. Although a great deal was learned by studying these charges not much practical use could be made of static electricity. In the first place it was produced by friction and large quantities of it could not be obtained easily. Secondly, when it was produced in large amounts the potential was so great that it was dangerous to handle and difficult to store. Static

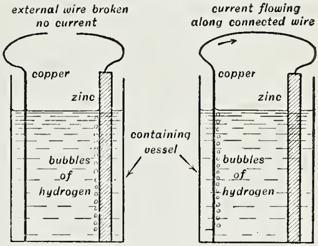


Fig. 218.—A Voltaic Cell

electricity destroyed but did not build. It was therefore a great step forward when Volta, an Italian scientist, discovered that electricity could be produced chemically. He discovered that when two metal plates such as zinc and copper were placed

in salt water that a current of electricity would flow through a wire which joined the plates. The electricity was produced by the chemical action of the salt and water on the plates. This device for producing a current of electricity is called a Voltaic cell. These Voltaic cells produce steady flowing currents of electricity at low voltage.[1] Since Volta's discovery it has been found that other chemicals than salt are more satisfactory for producing electric currents.

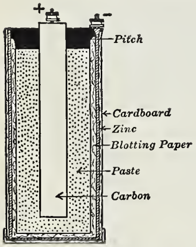


Fig. 219.—A Sectional View of a Dry Cell

Producing Electricity with Chemicals. A very good cell can be made by using weak sulphuric[2] acid with copper and zinc plates. (See illustration, Fig. 218).

You can make such a cell by pouring a little sulphuric acid into a glass tumbler containing water. Now place in the liquid polished copper and zinc plates, taking care that the two plates are joined by a wire. Electrons will flow along the wire from the zinc plate to the copper plate. These moving electrons are the current of electricity. Electrons will not flow unless the two plates of the cell are joined by means of a conducting wire. In the cell the chemicals cause electrons to leave

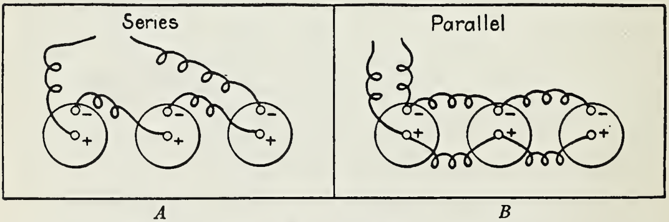


Fig. 220.—Series and Parallel Connections

[1] The voltage of an ordinary dry cell is about one and a half volts. The volt has been named after the scientist Volta.

[2] Be careful not to get sulphuric acid on your clothes or skin. It produces severe burns. When diluting strong sulphuric acid with water ALWAYS pour the acid into the water. If you pour the water into the acid an explosion may result and you may be splashed with acid.

the copper plate and to accumulate on the zinc plate, so that the copper plate becomes positively charged while the zinc plate is negatively charged. When a conducting wire joins the two plates the electrons then flow back to the copper (+) plate through the wire. This completes an electric *circuit* or circle. In order to stop the flow of electricity the circuit must be broken by disconnecting the copper wire (Fig. 218).[1]

Notice that bubbles of gas[2] collect on the copper plate as the chemical action which produces the electricity takes place. The cell you have just made should be able to ring an electric door bell. Connect a wire from each plate to the binding posts of a bell. How long does it ring?

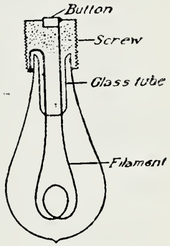


Fig. 221. An Incandescent Lamp

Dry Cells. Cells containing acid are not always convenient and therefore the modern "dry" cell (Fig. 219) was developed. The "plates" of a dry cell are zinc and carbon. The zinc plate is made in the form of a can to hold the other materials of the cell. Instead of acid a paste of moist sal-ammoniac (ammonium chloride) is used. A carbon plate (or rod) is in the centre of the can. Around the carbon is a black powder which contains a chemical,[3] to use up the hydrogen gas which is formed around the carbon when the cell is in use. In order to prevent spilling and drying up of the moist sal-ammoniac the cell is covered at the top with sealing wax.

When the cell is producing a current of electricity the zinc

1 Although electrons move through the copper wire from the zinc plate to the copper plate we say that the current of electricity moves from the copper plate to the zinc plate as shown by the arrow in the diagram. In the very early days, scientists thought that the electricity moved from the copper plate to the zinc plate. For this reason the custom has been established to indicate the current as flowing from the copper plate to the zinc plate.

2 The bubbles which collect on the copper plate are bubbles of hydrogen gas. In time they will entirely cover the plate and so prevent the acid from reaching it. The electric current will then stop flowing and the bell will stop ringing. The cell is then said to be *polarized* by the hydrogen gas.

3 Manganese dioxide. This prevents the gas from accumulating and the cell from being polarized.

plate becomes used up and the cell "runs down". In dry cells the chemicals also become used up and so the cell "wears out".

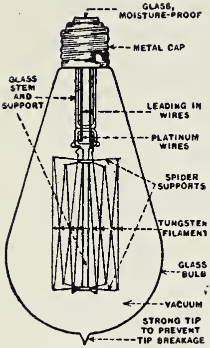


Fig. 222.—A Mazda Lamp

For convenience in attaching wires, the plates of a dry cell are fitted with binding posts, or *terminals*. The zinc post is known as the negative terminal and the carbon post as the positive terminal.

Batteries. An electric cell does not produce a very large current. If more electricity is needed it can be obtained by connecting a number of cells in *parallel*—that is by connecting all the positive and all the negative terminals of a number of cells (Fig. 220B). If a higher voltage is needed the cells are connected in *series;* that is, the positive terminal of one cell is connected to the negative terminal of the next and so on (Fig. 220A). The greater the number of cells used the greater will be the voltage produced. When a number of cells are connected in this way to produce either more electricity or higher voltage they make up what is called an electric *battery*.

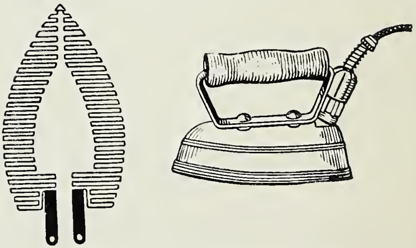


Fig. 223.—An Electric Iron

The "element" by which it is heated is shown separately. The element is resistance wire wound on sheets of mica.

Why We Can Use Current Electricity. Current electricity is very useful. You will recall that it was difficult to use static electricity. The charge of static electricity was always on the surface of an object and when an electric discharge took place all the electricity moved at once and

then remained static or standing on the next object. Not much work could be done with it. You might compare static electricity with the drops of water which fall during a thunder shower. Current electricity can be compared with the same drops which have joined together to form a river. The drops of water which fall in the shower cannot be easily made to do useful work but when they all flow steadily and quietly in a stream the water can be used to turn mill-wheels.

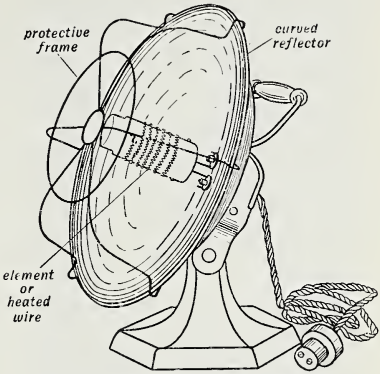


Fig. 224.—An Electric Heater
The resistance wire or element is wound on a porcelain cylinder.

The difference between static and current electricity is that current electricity flows steadily.

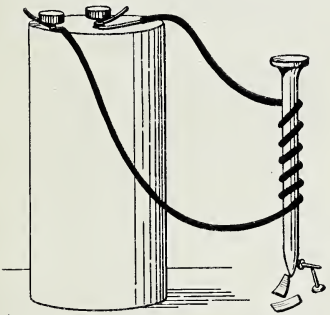


Fig. 225.—A Simple Electro-Magnet

Resistance. By means of a copper wire join the positive and negative poles of a dry cell. Notice that the copper wire becomes heated. Although copper is a good conductor, it resists, to a slight extent, the passage of electricity along it. This *resistance* creates heat. Certain other metals have a greater resistance to an electric current. This fact is made use of in the construction of electric heaters, stoves, toasters and irons (Figs. 223, 224). Heat is produced in these articles by allowing electricity to flow along coils of resist-

ance wires. When the electricity is turned on the resistance of these wires to the current causes them to become red hot.

The fine resistance wires in a modern electric light bulb (Fig. 222) are usually made of tungsten. When an electric current passes along the tungsten, light is produced because the wires be-

A .— B —... C ... D —.. E . F .—. G ——.
H .... I .. J —.—. K —.— L —— M —— N —. O . .
P ..... Q ..—. R . .. S ... T — U ..— V ...—
W .—— X .—.. Y .. .. Z ... . & . ...

Fig. 226.—The Morse Code

come white-hot, or *incandescent.* To prevent these thin wires from burning they are enclosed in a glass bulb from which the air has been removed.

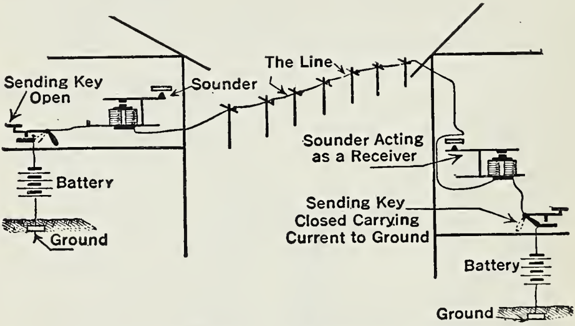


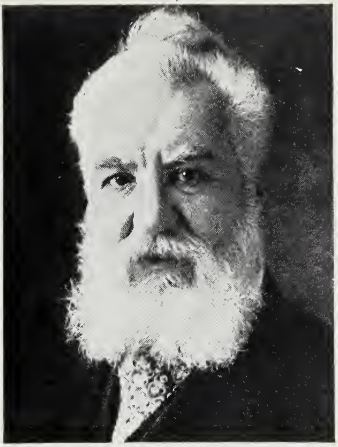
Fig. 227.—Diagram of a Telegraph Circuit

Why should the key at the receiving end be closed when a message is being sent from the other end of the line?

Tungsten is used as a filament because this metal has a very high melting point. The filament is very fine because the finer the filament the greater is the resistance which it offers to an electric current. We know that the passage of an electric current through a conductor is in reality the passage of countless electrons. If

their path suddenly becomes narrow the friction and resultant heat and light, caused by their passage, are great.

Electro-Magnets. A useful application of electric currents is the production of electro-magnets which attract pieces of iron. It was discovered that when a coil of wire was wrapped around a piece of soft iron and a current of electricity was passed through the wire, the soft iron immediately became a magnet (Fig. 225). The magnetized iron would then attract other pieces of iron just as if it were a magnet. This magnetism of the iron lasted as long as a current continued



Courtesy Bell Telephone Company of Canada

Fig. 228.—Alexander Graham Bell, the Inventor of the Telephone

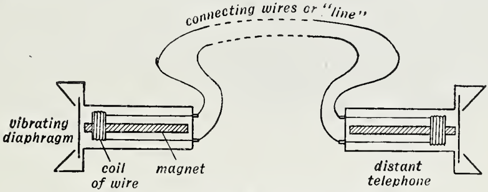


Fig. 229.—The Bell Telephone

You can make a simple telephone by joining together two telephone receivers by means of copper wire as shown in the diagram. When you talk into one receiver similar sounds will be heard from the other. The sound of your voice causes a thin, iron disk (the diaphragm) to vibrate. The vibrating disk generates small, electric currents in the coil of wire around the magnet. These currents in turn travel through the connecting wires or line to the other receiver (the distant telephone) where they pass through the coil, making it an electro-magnet. The electro-magnet attracts the iron disk, causing it to vibrate and thus to produce sounds similar to the voice.

to pass through the wire coil. As soon as the current was turned off the magnetism disappeared.

The Electric Telegraph. The electro-magnet is useful in many ways. For instance, in the electric telegraph (Fig. 227), currents of electricity are sent long distances through wires. These currents pass through the coil of an electro-magnet at the end of the wires. This electro-magnet then attracts a small iron rod and causes it to move up and down as the sender of the message turns the current on or off. This moving rod strikes a sounding board. A certain number of taps on the sounding board mean a letter of the alphabet. In this way a code is formed. By means of a code such as the *Morse Code* (Fig. 226), a message can be tapped out

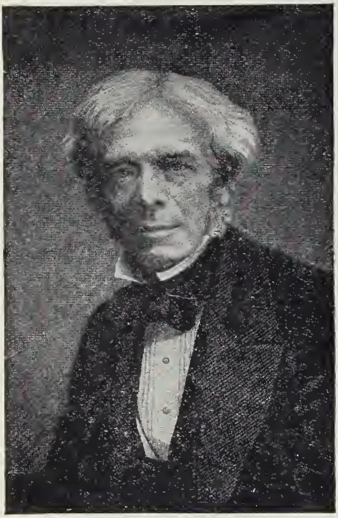


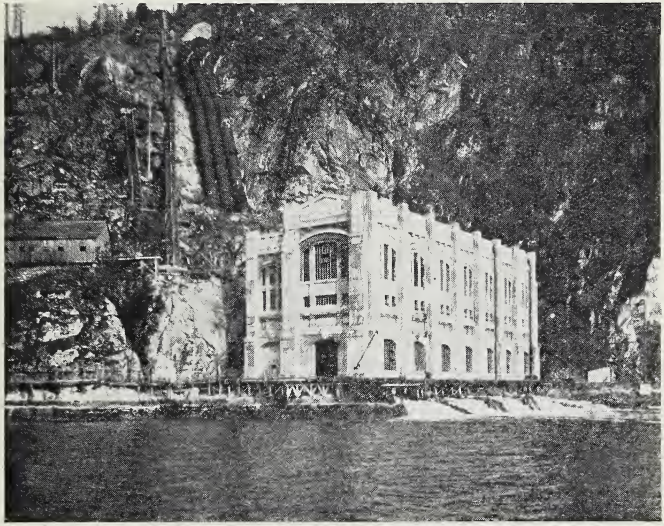
Fig. 230.—Michael Faraday

Electro-magnets made possible, not only telegraphs, but also telephones and radios. The receiver of a telephone and the speaker of a radio contain electro-magnets. This magnetism causes a thin, iron disc to vibrate. These vibrations in turn produce sound (Fig. 229).

The iron striker of an electric bell is caused to move by an electro-magnet. Electric motors also depend upon the principle of the electro-magnet.

The Dynamo. The fact that electricity can be used in so many ways makes it valuable to man. However, so long as the only source of electric power was the chemical battery, electricity

did not come into general use. The chemicals and materials needed in voltaic cells were too expensive for much electricity to be used from that source. A cheaper source of electrical power had to be found.



Courtesy B.C. Electric Railway Co.

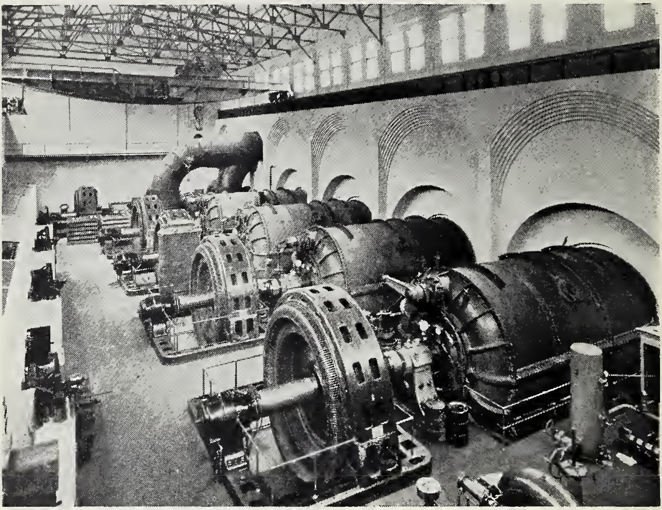
Fig. 231.—Lake Buntzen Power-House

Water from the lake above is used to drive the electric generator in the power-house. How does the water reach the power-house?

This was discovered by the Irish scientist, Michael Faraday (Fig. 230). He noticed, when he joined the ends of a coil of wire and moved it near a magnet, that a current of electricity moved through the wire. This discovery pointed the way to a source of cheap electric power. Dynamos which *generated* or produced electric power were constructed. These dynamos consist principally of a coil of wire called an *armature*. This armature is surrounded by powerful magnets. Electricity is caused to move in the wires

by revolving the armature between the magnets. The electricity thus generated is conducted by wires to all parts of the community.

Power to revolve the armatures of the dynamo may be obtained from various sources. Where waterfalls and rivers are plentiful water power is used. In other places the dynamos are driven



Courtesy B.C. Electric Railway Co.

Fig. 232.—Interior of a Power-House

Water passes through the large turbines on the right where it drives vanes or paddle-wheels. These vanes are attached to the axles. As the axles spin they drive the armatures of the generators on the left.

by steam. The use of water power or steam makes it possible to produce electricity so cheaply that it can be used to drive the motors of street cars or to turn the wheels of factories. This abundant electric power brightens our homes and runs electric devices which lighten the load of our labours.

Guide Words

thunderbolt
negative
series
generator
attract
Voltaic cell
electric motor
electrons
current electricity
telegraph
electricity
positive
non-conductors
electric discharge
repel
electro-magnet
induced charge
protons
battery
dynamo
static
conductor
parallel
pith ball
resistance
electric light
potential
electric heater
electroscope

Signpost Sentences

1. .... can be produced by friction.
2. Charges of static electricity are produced by rubbing together two ....
3. There are two kinds of electric charges, ... and ....
4. A .... charge of electricity can be produced on an ebonite rod by rubbing it with cat's fur.
5. A glass rod can be charged with .... electricity by rubbing it with silk.
6. Like charges .... one another; unlike charges .... each other.
7. All substances contain particles of both positive and negative ....
8. The negative particles of electricity are called ....
9. .... can move from one substance to another.
10. Positive particles of electricity or .... remain within a substance.
11. .... consists of electrons moving in a circuit.
12. A current of electricity can be produced chemically by means of a ....
13. .... can be used:
    (*a*) to produce heat; (*b*) to produce light; (*c*) to operate electro-magnets; (*d*) to turn motors.
14. Moving water can be used to generate a current of electricity by allowing the water to turn the armature of a ....

Questions on the Chapter

1. What did Thales discover when he rubbed amber?
2. How could you produce an electric charge on a piece of sealing wax?
3. Name several good conductors and several non-conductors of electricity.
4. How could you show that a substance has an electric charge in it?
5. How could you demonstrate that unlike charges attract each other?
6. Explain how a negative charge is produced when an ebonite rod is rubbed with cat's fur.
7. How could you prove that a positive charge was produced on the cat's fur at the same time?

8. Why does a spark jump when you hold your finger near a charged ebonite rod?
9. How did Franklin prove that lightning was an electric discharge?
10. What methods of protecting buildings from lightning did he suggest?
11. How would you make a simple voltaic cell?
12. Why does an electric current produce heat in a wire?
13. How can an electric current be made to produce light?
14. Describe how you would make an electro-magnet with a dry cell, a piece of wire and an iron nail.
15. How is the electric current which is used in your home produced?
16. Name several devices which use electro-magnets.

Special Problems and Practical Applications

1. Why does a truck which is carrying a tank of oil or gasolene, drag a chain along the ground?
2. If, in the winter time when the air is very dry, you shuffle on a woollen carpet and then touch a radiator you may notice a spark jump. Can you explain why?
3. Study the electric devices in your home. Which of them depend for their operation on (a) resistance? (b) electro-magnets? (c) electric motors?
4. Why are copper wires generally used to carry currents of electricity?
5. The resistance wire in a fuse-plug melts at a fairly low temperature. How does this prevent the wiring in your home from being overheated by electric currents which are too large for them to carry?
6. Some electric trams use only one overhead wire. How is the electric circuit to the power-house completed?
7. Why are telephone, telegraph, and other electric wires strung on glass supporters?
8. A number of inventors have used electric currents in their inventions. Read the life stories of such inventors as Alexander Graham Bell Guglielmo Marconi, Thomas A. Edison. What electrical devices did they invent? Report your findings to the class.

Home Projects

1. You can make a toy electric circus from a cigar box, a sheet of glass and some tin-foil. Cover the bottom of the box with tin-foil. From thin paper cut out small figures of animals and acrobats. Place them in the box and then cover it with the glass. With a piece of silk rub the glass briskly. The figures will be alternately attracted and repelled by the electric charge on the glass and will dance about in a life-like manner. (See Fig. 216).
2. Construct an electro-magnet by wrapping cotton-covered copper wire around an iron bolt. Connect the ends of the wire to a battery of dry cells.
3. Automobiles are provided with dynamos which generate electricity when the motor runs. Examine the dynamo of an automobile and report to the class as follows: (*a*) how the armature of the dynamo is made to revolve; (*b*) where the electricity is stored; (*c*) the devices on the car which depend upon electricity to operate them.

UNIT X

CHANGES WHICH OCCUR IN MATTER

CHAPTER XXI

CHEMICAL CHANGE

Can you answer these questions?

1. Of what is water composed?
2. Why does iron rust?
3. Why does paint prevent iron from rusting?
4. What becomes of wood when it is burned up?
5. Why does water put out a fire?
6. Could you obtain a metal from salt?
7. How do chemists produce new chemicals?
8. How are metal objects silver-plated?
9. How does a camera take a picture?
10. Why does sugar turn black when it is burnt?

What is Matter? Every day you see and handle different kinds of common materials such as chalk, cheese, wood, water, stone, sugar. We call all these materials "matter". Are wood and water but different forms of the same kind of matter or are they different kinds of matter? These very questions puzzle you; they also puzzled the thinkers of former times. Their experiences suggested to them that all matter was connected in some way with what they called the elements. They believed that all things were made of one or more of these elements. They saw that when a tree was planted it grew up into a trunk and branches composed of wood. The wood did not exist before the seed was planted. It was made from the earth, water and air

as the tree grew. When the wood was burned it produced fire. A cold object held in the flame became covered with drops of water. From the flame came a gas which they thought was like air, and when the wood was burned up an earth, or ash, remained. Since, in a like manner, they obtained some or all of these four substances from other materials they concluded that all matter was made up of these four things—earth, air, fire, water. They called them the elements. They believed that the elements could not be broken up into simpler substances and that each element is, in itself, a complete substance. Were they correct? Is water

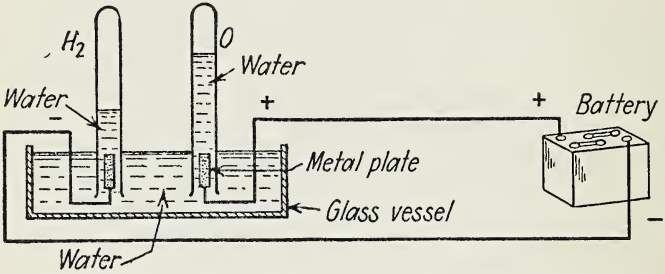


Fig. 233.—Breaking Up Water into Oxygen and Hydrogen, the Elements Which Compose It

really a true element? Can it be broken up or decomposed into simpler substances? In their studies of the nature of matter the ancients did not have the means and apparatus which scientists now have. If they had been able to use electric currents they might have decomposed the water which they thought was a true element. By using an electric current you may prove by decomposing it that water is not an element.

Problem

Is water an element or is it made of other simpler substances?

Plan. If an electric current is passed through water, the water may be decomposed.

Apparatus. A dish of water, dilute sulphuric acid, two lengths of

copper wire, (on one end of each piece of wire a piece of platinum foil should be soldered. These two platinum strips are called electrodes. The copper wire should then be coated with shellac. Care should be taken to keep the platinum electrodes free from the shellac). Two test-tubes, a storage battery or a battery of dry cells connected in series.

Method. Add a little of the sulphuric acid to the beaker of water.[1] Fill the two test-tubes with the solution, invert them and place them in the dish as shown. (A piece of paper placed over the open end of the filled test-tubes will enable you to place them more easily.) Insert the platinum electrodes in the test-tubes. Connect the other ends of the wires to the terminals of a battery. Allow the test-tubes to fill with gas and test the gas with a glowing splint.

Observations. 1. Does a current of electricity pass through the water? 2. Do you notice bubbles of gas collecting on the platinum electrodes? 3. In which test-tube does most of the gas collect? 4. What kinds of gas collect in the test-tubes?

Conclusion. Can water be decomposed into other substances? Is water an element?

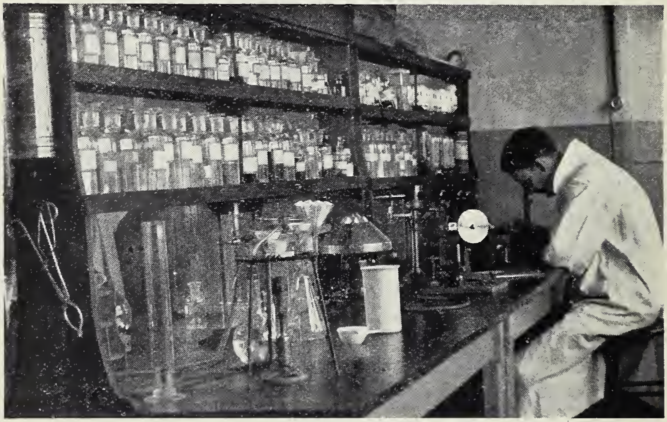
The Elements. In this experiment you have discovered that the early thinkers were mistaken about water. Water is not an element. It can be broken up or decomposed into two gases. One of these gases burns and we know it to be hydrogen. The other gas causes a glowing splint to burst into flame. It is oxygen. Water is composed of hydrogen and oxygen.

It is clear then that water is not an element but is composed of hydrogen and oxygen. Can these two gases be broken up into simpler substances? Scientists as yet have not been able to do so. For this reason and for other reasons we call hydrogen and oxygen *elements*.

Hydrogen and oxygen are but two of the elements which scientists have discovered. By experimenting with many substances scientists have discovered ninety-two different elements. Some of these elements are gaseous like oxygen, some are liquids and some are solid. You are already familiar with many elements. The following is a list of the more commonly known ones. Check over the list and note the ones you know. Which are gases, which are liquids and which solids?

[1] Pure water is a poor conductor of an electric current. In order to make it conduct the current readily sulphuric acid is added. The sulphuric acid also plays an active part in decomposing the water but the acid itself is not used up.

hydrogen	oxygen	phosphorus
iron	nickel	copper
mercury	sulphur	nitrogen
chlorine	neon	tin
helium	aluminium	platinum
zinc	carbon	gold
silver	lead	magnesium
radium	tungsten	sodium



Courtesy Ayerst, McKenna and Harrison, Limited

Fig. 234.—A Chemist at Work in the Laboratory

Compounds. There are many thousands of different substances. Only ninety-two of them are elements. What are the others? Of what are they made? Water is one of these other substances. As you discovered it is composed of two elements—hydrogen and oxygen. Like water, other substances are also composed of elements. The various kinds of substances do not, however, all contain the same elements. Carbon dioxide is composed of carbon and oxygen; wood is composed of carbon, hydrogen and oxygen; table salt is composed of sodium and chlorine.

Substances which, like these, are composed of two or more different elements are called compounds. Water, wood, carbon dioxide and table salt are compounds. Though there are only ninety-two elements, these ninety-two unite to form many thousands of compounds.

Atoms. Dalton, an English scientist, over a century ago explained how elements form compounds. He said that the elements are composed of very small particles or *atoms*. The atoms of each element are all alike, but the atoms of one element are different from the atoms of any other element. Atoms join together to form molecules. When atoms of the same element join together they form *molecules* of the element. When atoms of different elements join together they form molecules of a compound. A drop of water contains many molecules. We have found that each molecule of water contains two atoms of hydrogen and one atom of oxygen. The chemist writes H_2O to represent a molecule of water. Molecules of water can be broken up so that the hydrogen and oxygen atoms of which they are composed are set free.

The Science of Chemistry. Molecules by themselves cannot be seen even with the most powerful microscope. They are so small that it is difficult to imagine their size. It has been estimated that if a drop of water were magnified to the size of the earth the molecules in it would be no larger than golf balls.

The science of chemistry is chiefly a knowledge of the elements and their many compounds. The chemist studies to learn how to decompose or break up compounds into elements and how to make compounds by uniting elements. You saw how water was decomposed by an electric current. Many other compounds can be decomposed in this way. Other compounds can be decomposed by heating them. As an example of this, place a little mercuric oxide in a test-tube and heat the test-tube; the compound mercuric oxide is decomposed into the elements mercury and oxygen (Fig. 235). You can detect the oxygen by thrusting a glowing splint into the test-tube. The mercury will be

seen as a silvery coating on the sides of the test-tube. Other compounds are decomposed when light shines upon them. This makes photography possible. There are still other ways of breaking up compounds.

Building Compounds. The chemist has also a knowledge of how to build up the molecules of compounds from the atoms of elements. When materials burn, the elements in them unite with atoms of the oxygen of the air and form new compounds. That is why oxygen is necessary for burning. The atoms of elements are not destroyed by the burning; they become part of the new compounds. When wood burns the materials of the wood seem to be destroyed because the new compounds are invisible gases. The hydrogen of the wood unites with oxygen to form invisible water vapour and the carbon unites with oxygen to form invisible carbon dioxide. When elements unite with oxygen we say that they are *oxidized* and the new substance is called an oxide. Carbon dioxide is an oxide of carbon; water is an oxide of hydrogen. When fuels burn they are becoming oxidized rapidly by the oxygen of the air. A burning fire is an example of *rapid oxidation.* When iron rusts the iron is becoming oxidized and the iron rust so formed is an oxide of iron. This takes place slowly and is called *slow oxidation* (Fig. 236).

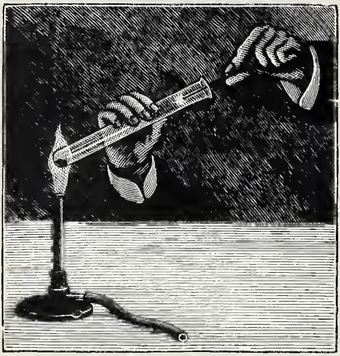


Fig. 235.
When mercuric oxide is heated it is decomposed into its elements, mercury and oxygen. The oxygen will cause a glowing splint to burst into flame.

You have seen how molecules of water were decomposed into hydrogen and oxygen. Hydrogen and oxygen can be combined

again to form water by burning the hydrogen in oxygen. You can show this by holding a cold object in a flame of burning hydrogen. The water vapour formed when the hydrogen and oxygen unite will condense upon the cold object (Fig. 237).

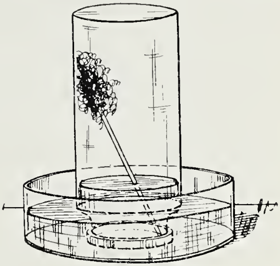


Fig. 236.

Oxygen is used up when the steel wool rusts. The water rises in the jar to replace the oxygen. Why does the water rise to only one-fifth of the height of the bottle?

One would not have suspected that water is composed of two gases. How unlike either of the gases the water is! Hydrogen burns explosively. Oxygen makes a fire burn fiercely. Water is used to put out fires. When elements combine to form new compounds the nature of the elements is entirely hidden in the new compound. No one by looking at a compound could guess what elements it contains. For example, you have often tasted salt and eaten it with your meals. You did not suspect that the salt was composed of two elements; one of them is a metal—the other is a gas. Salt is a compound formed by uniting atoms of sodium with atoms of chlorine. Sodium is a soft silvery metal. It reacts violently when it becomes wet. No one would think of eating it. If you were to swallow half as much sodium metal as the salt you swallow during a meal you would be killed.

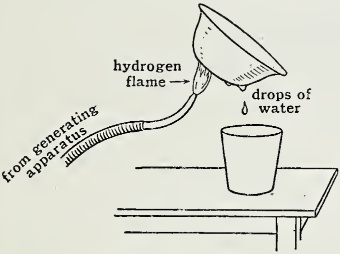


Fig. 237.

When hydrogen burns in air water is formed.

Chlorine is a poisonous gas. There is enough chlorine in the salt of one meal to poison you. Yet when these two are combined they

form the crystals of salt, and salt is a necessary part of your food. It would be difficult for you to decompose salt but you can do an experiment to discover what elements are in the compound sugar.

If you place a little sugar in an iron spoon and heat the spoon the sugar gradually turns black. The black material is charcoal or pure carbon. The heat decomposes the sugar into carbon and water vapour. Sugar, therefore, is a compound of black, tasteless carbon and colourless, tasteless water. You know that water is composed of hydrogen and oxygen. Therefore each molecule of sugar contains atoms of carbon, hydrogen and oxygen. It is easy to decompose sugar but it is not easy to make it. If you were to mix carbon and water the black carbon would float in the water. You could see that both water and carbon were in the mixture but there would be no sugar in it. The compound sugar does not resemble in any way the mixture carbon and water. In order that sugar may be formed, atoms of carbon must unite with atoms of hydrogen and atoms of oxygen to form molecules of sugar. Causing these three to unite is difficult, they will unite to form sugar only under certain conditions. Building molecules requires knowledge and skill. Chemists have this knowledge and skill.

Some Practical Uses of Chemistry. Many of the materials which enrich our modern life are produced through the skill of the chemist. Aluminium is one of such materials. Aluminium is a metal which has many uses. Not many years ago it was unknown, although ores which contain it are quite plentiful. When chemists learned how to separate the aluminium from its compounds by using an electric current the metal became plentiful and was turned to many uses. Many other metals are made plentiful because of the methods which chemists have devised for getting them from their ores. Although gold and platinum are found as elements most of the other metals which are used today are found as compounds. Iron, for example, is usually found as oxide of iron. In order to get pure iron the oxygen

must be removed from the compound. This cannot be done easily. Heating alone is not sufficient. The atoms of oxygen are too firmly fixed to the atoms of iron in the molecules of iron oxide.

The oxygen is separated from the iron in the following manner. Carbon, or coke, is mixed with the iron ore; the mixture of the two is heated highly in a special furnace called a blast furnace (Fig. 238). The heated carbon unites with oxygen and takes the oxygen away from the iron oxide. This leaves pure iron which melts with the heat. The melted iron is run into moulds. It is then called pig iron. The carbon and oxygen form carbon dioxide which goes off into the air through the chimney of the furnace. This process of getting metals from their ores is called smelting.

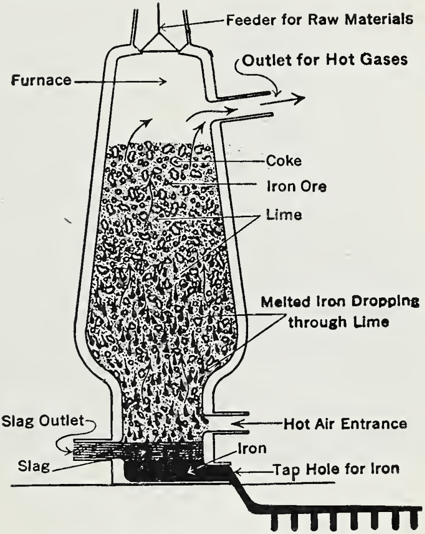
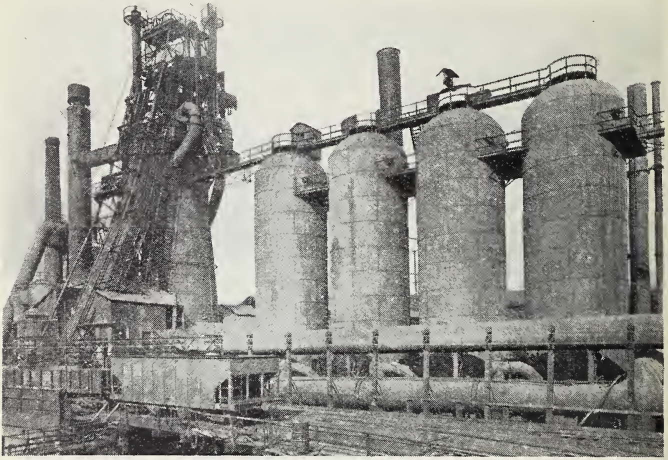


Fig. 238.—A Blast Furnace for Smelting Iron

Lime is mixed with coke and iron ore (iron oxide). The lime fuses with the impurities in the iron ore and forms a *slag*. The slag floats on the melted iron and is drawn off through the outlet shown.

How Salts Are Produced. You are familiar with table salt. It is one of the many different salts that chemists use. Salts are compounds. Molecules of salts usually contain atoms of some metallic element combined with atoms of other elements. Salts

of different kinds can be made by allowing acids to act upon metals. You should be able to find some acids in your home. They are sour to the taste. Lemon juice, vinegar and sour milk contain weak acids. You can prove that these substances contain acids by tasting them and testing them, as the chemist does, with blue litmus paper. Acids turn blue litmus paper red. The



Courtesy Steel Company of Canada, Limited

Fig. 239.—General View of Blast Furnace for Reducing Iron Ore to Iron

chemist, however, usually uses much stronger acids than these. Sulphuric acid, nitric acid and hydrochloric acid are three strong acids which chemists use.[1]

All acids contain hydrogen atoms. When certain acids are poured upon some metals the atoms of hydrogen are given off and atoms of metal take the place of hydrogen atoms in the

[1] An inexperienced person should not use strong acids without careful instructions. They are dangerous to handle. If they splash they will burn the skin and clothing and they may cause serious damage to the eyes. If splashed with strong acids the clothes, skin or eyes should be washed immediately with a large amount of water.

molecule of the acid. The new compounds, thus formed, are salts. The following experiment shows how an acid can be used to prepare a salt.

AIM

To produce a salt by allowing an acid to act upon a metal.

Plan. Most metals produce salts when placed in certain acids. Zinc should produce a salt if it is placed in hydrochloric acid.

Apparatus and Materials. Some zinc metal, a small flask, some diluted hydrochloric acid and a beaker.

Method. Place a small amount of zinc in the flask and pour some hydrochloric acid in it. After the zinc has all disappeared pour the liquid which remains into the beaker. Allow the beaker to stand on a warm stove until the liquid evaporates.

Observations. 1. When the acid was poured on the metal did you see bubbles of gas come off? You will recall that you made hydrogen gas in this manner in Chapter VIII. 2. As the liquid evaporated did you notice crystals of salt forming?

Conclusion. Do hydrochloric acid and zinc metal produce a salt?

The salt made by the action of hydrochloric on zinc is called zinc chloride. Whenever hydrochloric acid acts on a metal a chloride salt is formed. Table salt is sodium chloride. Salts made from metals and nitric acid are called nitrates; for example, sodium nitrate. Metals and sulphuric acid form sulphates such as zinc sulphate and copper sulphate.

Electroplating with Salts. Salts have many uses in industries. Copper sulphate or blue stone, as it is commonly called, forms a poison when it is dissolved in water. This solution is used to kill insects and fungous growths in the garden. Copper sulphate is also used when it is desired to cover a metal object with copper. When an object is so covered it is said to be copper-plated. As this is done by using an electric current, the process is called electroplating. The metal object to be electroplated is attached by a piece of copper wire, to the negative terminal of a battery. The object then becomes an electrode. It is placed in a vessel containing a solution of copper sulphate so that it is completely covered by the solution. The positive terminal of the battery is connected by another wire to a piece of copper which is also placed in the solution. As the electric current flows

through the solution pure copper from the copper sulphate is deposited evenly over the object which is to be plated (Fig. 240).

By using salts of nickel instead of copper sulphate the metal object could have been plated with nickel. Because nickel does not rust or tarnish many metal objects are nickel-plated. The nickel prevents the air from reaching the other metal and therefore rusting is prevented.

If a salt containing silver were used the metal objects could be silver-plated. People admire the silver lustre on tableware. Pure silver, however, is costly. Cheaper metals when silver-plated make good substitutes for solid silver.

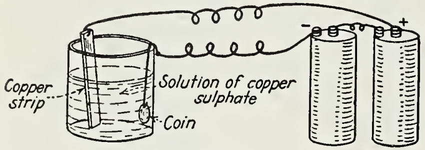


Fig. 240.
Observe that the article to be plated is attached to the negative terminal of the battery.

Gold-plated jewellery is less expensive than solid gold. Metal objects can be plated with gold in the same manner in which copper plating is done by using salts containing gold instead of copper.

Photography. Some compounds are decomposed by light. Salts containing silver turn black when exposed to light because they have been decomposed. Knowledge of this fact has led to the making of photographic plates and films that are sensitive to light. The sensitive plate or film is covered with a coating of gelatine which contains a silver salt such as silver chloride. When light falls upon the prepared plate some of the silver salt is decomposed. When a picture is desired the plate or film is placed in a camera. The lens of the camera causes an image or picture to fall upon the sensitive plate or film (Fig. 241). The lighter parts of the picture cause more decomposition than the darker parts. In order to see the decomposition thus produced the plate or film must be developed by using chemicals. When it is developed the light parts of the original picture appear dark and

the dark parts appear light. Because of this the developed plate or film is called a negative. The developing is done by placing the plate or film in a solution containing several chemicals. Sodium sulphite, carbonate of soda and pyrogallic acid are chemicals often used in a developing solution.

When the negative is developed it must be *fixed*. If this is not done, then the silver salt which is not yet decomposed, will turn black and spoil the negative when the negative is exposed to more light. The *fixing* is done by removing the silver salt which has not been decomposed. To do this the negative is placed in a solution of hyposulphite of soda. This solution is commonly called *hypo*.

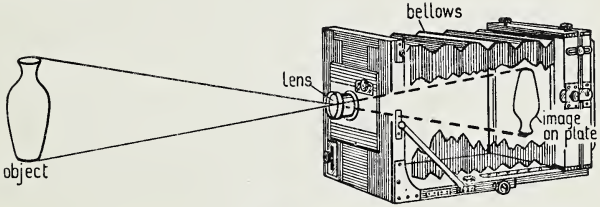


Fig. 241.
Note that the image on the plate at the back of the camera is inverted.

To make a print, or a positive picture, the negative is placed over a piece of sensitized paper. The surface of this paper is coated with a gelatine containing silver salt, just as the plate or film is. When light shines through the negative upon the sensitized paper the silver salt is partly decomposed as it was on the negative. The positive is now developed and fixed in the same manner as the negative was fixed. From one negative many prints can be made in this way. Procure some printing-out paper or proof paper from a photographic shop. You can make shadow pictures with it. To do this place a flat object such as a fern leaf or a key on the shiny side of the paper. In order to hold the paper flat cover it with a sheet of glass. Now

expose the paper to the sunlight until it turns a reddish brown. On removing the fern or key you will find that there is an outline picture on the paper. The paper will darken entirely upon exposure to light. In order to keep the picture you must "fix" it. To do this dissolve a package of prepared "hypo" in water. (The directions are given on the package). Place the paper in the solution and allow it to remain there for about fifteen minutes. Wash the print afterwards in running water for fifteen or twenty minutes. By using snap-shot negatives you can print your own pictures in this way.

Etching. The fact that acids act upon metals and form salts which dissolve in water is of value in many trades. Printers, engravers and art metal workers use acids for etching metals. Your teacher can help you to etch a piece of copper so that you may see how it is done. Paint a design on a sheet of copper with liquid asphaltum (beeswax will do). Now place the copper in a glass tray which contains nitric acid. The acid will act upon the exposed copper to make a salt, copper nitrate. The salt will dissolve away. The painted design will stand out in relief when the asphaltum is rubbed off.

If you do not know why printers use copper etchings you should read an account of printing. You can find the information you require by consulting books in the library.

Guide Words

matter	elements	decomposed
compound	atom	molecule
rust	ores	litmus
copper-plating	sulphuric acid	nitric acid
platinum foil	electrodes	hydrochloric acid
carbon	salts	electroplating
Dalton	H_2O	microscope
charcoal	copper sulphate	chemist
mercuric oxide	oxidation	smelting
mercury	oxide	aluminium
chemistry	hydrogen	slow oxidation
rapid oxidation	mixtures	burn
chemicals	acids	metals

Signpost Sentences

1. .... may be either an element or a compound.
2. The smallest part of an .... is an atom.
3. The smallest part of a .... is a molecule.
4. A .... of a compound is composed of either two or more atoms of different elements.
5. The compound water may be decomposed into its elements, hydrogen and oxygen, by means of an ....
6. Compounds can be .... into their elements by various methods.
7. When .... is burned in oxygen, the compound water is produced.
8. When an element unites with oxygen, an .... is formed.
9. When fuels burn, ... takes place.
10. When substances oxidize slowly, as iron does when it rusts, the process is called ....
11. When fuels .... they disappear because invisible gases are formed.
12. When elements unite to form a .... the nature of the elements is changed and the new .... is quite unlike the elements which form it.
13. .... of elements are not compounds.
14. Metals, such as iron, copper and lead, are procured from their .... by smelting.
15. Table salt is one of the many different kinds of ....
16. Many salts are useful ....
17. .... are sour to the taste. They turn blue litmus red.
18. Certain acids act upon certain .... to form salts.
19. Objects can be coated with metal by the process of ....

Questions on the Chapter

1. What is an element?
2. How do you know that water is not an element?
3. How many elements are known to science?
4. Name ten elements with which you are familiar.
5. How do you know that compounds are composed of elements?
6. How large are molecules?
7. Mercury is secured from cinnabar or mercuric oxide. How is this done?
8. What becomes of wood when it burns?
9. How does iron rust?
10. How can you tell that a substance contains acid?
11. What precautions must you observe when you are handling strong acid?
12. How can you tell what elements a compound contains?
13. Explain how a metal object may be copper-plated.
14. Why are iron and steel objects such as skates and bicycle pedals nickel-plated?
15. How does light produce a picture on a photographic plate?

Special Problems

1. Why does a coat of shellac or paint prevent iron from rusting?
2. Sugar is composed of carbon, hydrogen and oxygen. How could you prove it?
3. What observations led the early thinkers to believe that there were four elements only?
4. Read about Dalton in the encyclopaedia and report on him to the class.
5. Why is it advisable to wrap a woollen blanket around a person whose clothes have caught on fire?
6. Aluminium, copper and chlorine are obtained from compounds by electrolysis. Refer to the library to find out how this is done. Report your findings to the class. (If you can, visit an industrial plant where one of these is made)
7. Lime and iron are obtained by heating compounds which contain them. Procure information about the industries which produce and use them.
8. How is cement made?
9. In what way does chemistry help in the manufacture of paper, artificial silk, explosives, celluloid?
10. Show how the moving picture industry depends upon the science of chemistry.

Home Projects

There are many chemicals around your house. Here is a list of some of the chemicals you may find at home:

Vinegar, javelle water (solution of chlorine), ammonia, table salt, calcium carbide, baking-soda, washing-soda, saltpetre, alum, borax, bluestone (copper sulphate), lye, soap, baking-powder, chloride of lime, sugar. You can use some of these to do interesting experiments such as are suggested in the following:

1. Make some carbon dioxide by putting vinegar on baking-soda. The acid decomposes the baking-soda and sets free the carbon dioxide gas.
2. Make some carbon dioxide by putting water on baking-powder. Baking-powder contains baking-soda and tartaric acid. The acid decomposes the baking-soda when the powder is wet.
3. If you place a little baking-soda in a bottle with vinegar and quickly insert the cork you can make a carbon-dioxide pop-gun.
4. Put some pieces of coloured cloth in javelle water. The cloth will be bleached. The chlorine in the javelle water causes the coloured compounds in the cloth to change colour.
5. Bleach some coloured cloth by putting it in a strong solution of chloride of lime.
6. Dissolve some blue-stone in water and put your knife blade in the solution. The blade will be copper-plated because some of the iron changes place with the copper of the copper sulphate and becomes iron sulphate. The copper is left behind on the knife blade.
7. Put a little calcium carbide on a piece of ice. (Do not handle the calcium carbide with your bare hands.)
8. Many people enjoy taking photographs but only a few ever take

the trouble to develop and print them. You can learn how to do this for yourself. You will find developing and printing pictures an interesting hobby.

9. Make a collection of elements and also a collection of compounds. Demonstrate your collections to the class.

10. You can do an experiment to show that iron uses oxygen when it rusts. Put some steel wool in a bottle and stand the bottle upside down in a saucer of water. As the steel wool rusts the oxygen in the bottle is used up. How does the experiment show this?

11. Smelt some lead oxide by mixing it with ground up charcoal and heating the mixture.

CHAPTER XXII

PHYSICAL CHANGES

Can you answer these questions?

1. Why does ice float?
2. Why does a thermometer show change in temperature?
3. Why does frost burst water pipes?
4. What becomes of sugar when it dissolves?
5. Why are clothes "dry" cleaned?
6. Why is soap used for washing?
7. What is the difference between hard water and soft water?

Physical Changes in Matter. In winter you have seen frozen water pipes. You have, on very cold mornings, turned on the faucet to draw water only to find that no water came. Then later, after you had lighted the fire and warmed the house, the ice in the water pipes melted. You then found that the water pipes were split and that water was spurting out of the cracks. What had happened to the water to make it change to ice? What caused the pipes to become damaged? Is ice a new compound which forms when water freezes? To answer these questions you must recall what you have learned about chemical change.

You know that when substances undergo chemical change they completely lose their identities and new substances of a different nature are formed. You will recall that two gases, hydrogen and oxygen, unite to form the liquid water; that when the red powder mercuric oxide is heated, oxygen and mercury are produced. The mercury and oxygen, however, do not become mercuric oxide again when the mixture is cooled. Ice *does* change back to liquid water when it is warmed: ice, then, is not a new compound but another form of water. The water undergoes a

decided change when it is frozen but the change is not a chemical change. We have another example of a change that is not a chemical change when water boils and changes to steam—a gas. When the steam becomes cooled it changes back to water. Heat can cause the form of water to change without changing the chemical nature of the water.

States of Matter. It is clear from these observations that there are three forms of water. It can be in the form of ice, a solid; or in the liquid form; or in the form of a gas, steam. If you examine other substances you will find that they, too, can

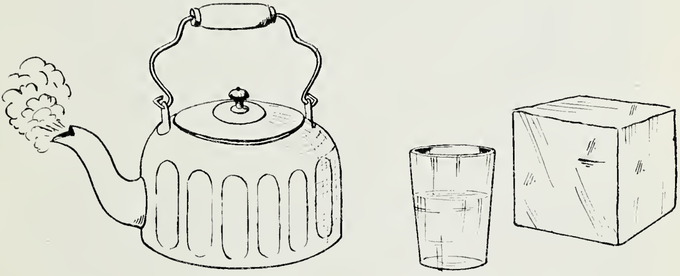


Fig. 242.—Three States of Water, Solid, Liquid and Gas

be changed in form by heating them. When you melt fat in a frying pan it becomes liquid but it still continues to be fat. Perhaps you have seen a plumber melting lead by heating it over a blow torch. The hot, molten lead changes back to solid lead when it is cooled. All matter is found in one or the other of the three forms, or *states*, of matter. It is either liquid, solid, or gaseous. Heat can change the state of many kinds of matter without causing chemical change.

This will help you to understand why the water pipes are split when they become frozen. When water becomes sufficiently cooled it changes from a liquid state to a solid state. When it

changes to the solid state it expands or increases in volume. This expansion of the freezing water bursts the pipes. During frosty weather it is important that the water be drained from pipes which are likely to freeze. Because of the expansion, ice is lighter than water. This is why ice forms at the top of the water. It also explains why ice floats. If a cubic foot of ice were melted, the water obtained from it would occupy only nine-tenths of a cubic foot (Figs. 243-244).

Fig. 243.

Because water expands about one-tenth of its volume when it freezes ice is lighter than water. This fact accounts for the floating of ice.

Effect of Heat on Matter. Heat has other effects upon matter besides causing it to change from one state to another. A bar of iron, if heated sufficiently, first becomes red hot and then white hot. The heat causes it to change colour. If you were to measure carefully the length of the bar of iron before heating it and after heating it you would find that the heated bar is longer. Heat causes an iron bar to expand. Heat also causes other matter to expand. You can demonstrate this by heating other substances.

Problem

To demonstrate that heat causes matter to expand.

Plan. As there are three states of matter you should try the effect of heat upon a liquid, a solid and a gas.

Apparatus. A brass ball which exactly fits a brass ring, a florence flask fitted with a one-holed stopper in which a length of glass tubing is inserted, a second florence flask and a toy balloon (Fig. 245).

Method. 1. Pass the ball through the ring. 2. Heat the ball and try to pass it through the ring while it is hot. 3. Fill the florence flask with water; insert the stopper and heat the flask. 4. Fit the balloon over the mouth of the other flask and heat the flask. 5. Allow the ball to cool and try to pass it through the ring. 6. Allow the florence flask with the water in it to cool. 7. Allow the flask of air to cool.

Observations. 1. Does the heated ball pass through the ring? 2. Does the water rise in the glass tube when the flask is heated? 3. Does the water in the tube lower when the flask cools off? 4. Does the balloon become larger when the flask of air is heated?

Conclusion. Does matter in each of the three states expand when it is heated and contract when it is cooled?

From this experiment you learn that as a general rule matter expands or gets larger when it is heated and contracts or gets smaller when it is cooled. You already know something about the nature of matter which might help you to explain this expansion and contraction; i.e., matter is composed of molecules. Scientists have learned that the molecules are constantly moving. They have also learned that heating causes them to move faster

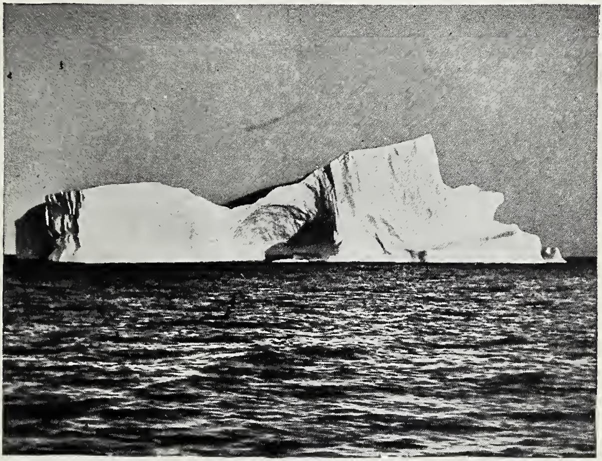


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Fig. 244.—A Floating Iceberg

The fact that nine-tenths of the iceberg is below water makes it dangerous for navigation.

and that cooling slows them up. When you heated the brass ball the molecules of which it is composed moved faster; they required more room in which to move, with the result that they moved farther away from each other. This caused the brass ball to expand. In the same way the heated water expanded and the heated air expanded. When the brass ball cooled again the

molecules slowed up and required less room in which to move and so the brass ball contracted.

Thermometers. Advantage is taken of the expanding of matter when it is heated, and the contraction of it when it is cooled, to measure temperature. An instrument which measures temperature is called a *thermometer.* It consists usually of a glass tube of fine bore with a bulb blown on one end. The bulb is filled with a liquid, usually mercury. When the temperature

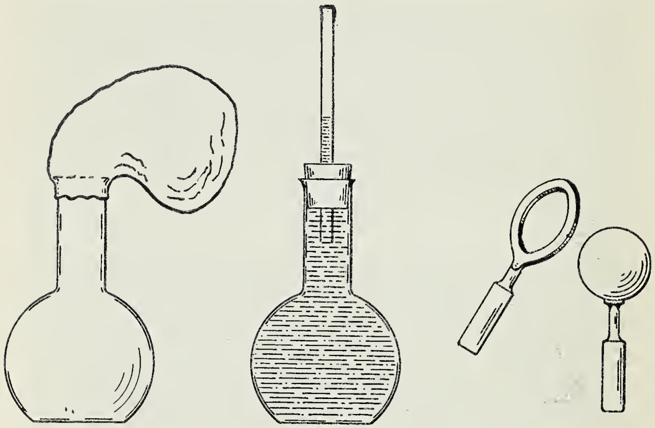


Fig. 245.—Apparatus Used to Show the Effect of Heat on Matter

increases the mercury expands and rises in the tube. When the temperature gets colder the mercury contracts and falls in the tube. By placing a scale beside the tube the amount of change of temperature can be noted.

You now understand why matter expands when it is heated. What causes it to change from one state to another? It is thought that when matter is in the solid state the molecules of which it is composed move back and forth in a limited space. When matter is in the liquid state the molecules move faster and

are therefore able to slide past one another. This allows the liquid to flow. In the gaseous state the molecules move so fast that they fly away from one another. Therefore a gas does not hold together but scatters in all directions.

When water is heated, a temperature is reached at which the water begins to boil. While it is boiling bubbles of steam are formed in the water. The liquid water changes rapidly into the gas, steam. If a thermometer be placed in cold water and the water heated, the mercury in the thermometer will expand and rise in the tube until the water commences to boil. The temperature at which this happens is called the *boiling temperature* or *boiling point of water.* As long as the water continues to boil the temperature does not change further. The mercury neither rises nor falls. We say that the boiling point of water is constant. The steam escaping from the boiling water also remains at the temperature of the boiling water.

On the other hand, if the water is cooled the mercury in the thermometer contracts and sinks in the tube until the water commences to freeze. This temperature is called the *freezing temperature of water* or the *freezing point.* The freezing temperature of water is also constant. While ice is melting it also remains at a constant temperature, called the melting point of ice. The freezing point of water and the melting point of ice are the same.

The Centigrade Thermometer. Because the boiling point and freezing point of water are constant they afford an easy way to make a thermometer scale. In order to mark the "degrees" on a thermometer the bulb is first placed in boiling water. When the mercury ceases to rise a mark is placed on the glass beside the top of the mercury. On a centigrade thermometer this mark is called one hundred degrees centigrade or 100°C. The thermometer is then placed in a mixture of ice and water. When the mercury ceases to fall in the tube a mark is placed on the glass opposite the top of it. This point is called *no degrees centigrade* or 0°C. The space on the tube between 0°C and 100°C is divided into one hundred equal parts. Each division represents

one degree centigrade. All thermometers made in this fashion will register the same at any temperature. For if they were placed in boiling water they would all register 100° C and if placed in freezing water they would all register 0° C. It is plain therefore that they will register the same at any temperature between 0° C and 100° C.

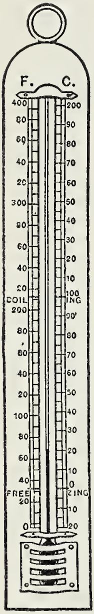


Fig. 246.—A Thermometer Showing both Fahrenheit and Centigrade Scales

The Fahrenheit Thermometer. The centigrade thermometer is in everyday use in many foreign countries. English speaking countries, however, use the Fahrenheit thermometer for ordinary purposes. In all countries the centigrade thermometer is usually used for scientific purposes. Fahrenheit thermometers are made in the same way that centigrade thermometers are made. The boiling point on the Fahrenheit thermometers is called 212° F and the freezing point is called 32° F. Figure 246 shows a comparison of the two scales.

You can test a thermometer to see whether or not it is correctly marked by first placing it in boiling water and noting if the mercury rises exactly to the boiling point and then placing it in a mixture of ice and water and noting if the mercury falls exactly to the freezing point.

The boiling point of water is changed when the air-pressure is changed. Water boils at 100° C at sea-level. It requires less heat to cause water to boil at higher altitudes than it does at sea-level. Therefore on the top of a mountain more time is required to cook food by boiling it because the temperature of the boiling water is lower than 100° C. On the other hand if the pressure is increased to greater than that at sea-level food will cook more

quickly and more thoroughly because the temperature of the boiling water will be greater than 100° C. For this reason pressure-cookers are used. These pressure-cookers are constructed with tightly fitting lids which are bolted on. As the water in them boils the steam which is produced increases the pressure. They are fitted with a safety valve which allows some of the steam to escape. If it did not escape in this way, the pressure would become so great as to burst the kettle.

Distilling Liquids. Many industries require for their success that the exact temperature be known. For example, crude oil or petroleum is a mixture of a number of different oils. These oils have different boiling temperatures. They can be separated by heat. When crude oil is heated the oil with the lowest boiling temperature boils off first. The vapour is condensed and the oil is obtained in a pure form. The other oils can be boiled off in the same manner one at a time by raising the temperature, in turn, to the boiling temperature of each oil in the mixture. By this process of distillation benzene, gasolene, kerosene, lubricating oil and petroleum jelly are obtained from petroleum (Fig. 248). You see from this how important is an accurate knowledge of

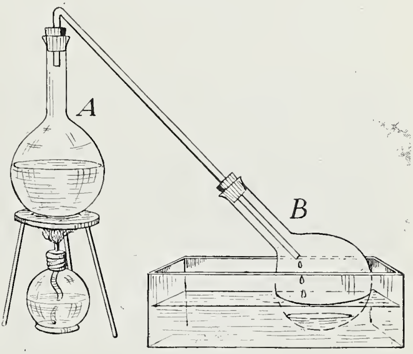


Fig. 247.
Water can be separated, by distillation, from salts which have been dissolved in it. The water containing the salt is placed in flask A. When the water is boiled the steam passes through the tube to flask B, where by cooling, it is condensed back into liquid form.

temperature in the refining of oils. Knowing the temperature of substances is very necessary in such industries as dairying, paper manufacturing and food canning.

Some Substances Will Dissolve in Water. You have learned that heat will cause changes in some substances without causing them to change their chemical nature. There are ways other than the use of heat to cause physical changes. When a teaspoonful of sugar is stirred in a glass of water the sugar seems to disappear. Its chemical nature has not changed; its sweetness can still be detected by tasting the water. The water and sugar

Courtesy Imperial Oil Limited

Fig. 248.—An Oil Refinery

form a *solution.* We say the sugar has been dissolved in the water. All the sugar can be recovered by allowing the water to evaporate. As the water evaporates crystals of sugar are again formed. In a like manner a solution of salt and water can be made. The salt can also be recovered by allowing the water to evaporate (Fig. 247).

Water is one of the most useful solvents (a *solvent* is a substance in which another substance dissolves. The substance which is dissolved is called the *solute*). More substances will dissolve in water than in any other solvent. Before the food which is eaten can be of use to the body it must either be dissolved in

water or it must be chemically changed in digestion to substances which will dissolve in water. Solutions are equally important to plant life. The mineral salts of the soil must be dissolved in water before plants can absorb them.

Some Substances are Insoluble in Water. There are many substances which will not dissolve in water. They are said to be insoluble in water. Glass, sand, wood, fat, iron, clay and copper are insoluble in water. Many more substances could be added to this list. Insoluble substances which consist of fine particles, like clay, form *mixtures* with water. The particles of clay merely float in the water and are said to be *suspended* in it. If the water stands the insoluble particles settle to the bottom and the water becomes clear. If it is desired to clear the water quickly the suspended particles may be removed by filtering. The water is filtered through a porous substance which strains out the particles. Substances which are dissolved in water cannot be removed by filtering.

Saturated Solutions. Sometimes boys complain that they can never make lemonade sweet enough for their tastes. When they add more sugar to make the lemonade sweeter they notice that it does not dissolve but settles to the bottom of the glass. No amount of stirring will make it dissolve. It is clear that there is a limit to the amount of sugar that can be dissolved in the quantity of water contained in a glass of lemonade. When water has dissolved all the sugar that it can hold, we say it is *saturated* with sugar or that it is a *saturated solution.* Saturated solutions can be made of many other substances; of salt, for example. If the same amount of water is used in each case, the amount of salt required to make a saturated solution of salt is less than the amount of sugar required to make a saturated solution of sugar. That is to say, salt is less soluble than sugar. As a rule, solid substances will dissolve in greater quantity in warm water than in cold.

Gases also dissolve in water. Fish depend for respiration upon the oxygen dissolved in water. Unlike solid substances, gases

dissolve less in warm water than in cold. If you allow a glass of cold water to become warm you will see bubbles of gas collect on the sides of the glass. The first bubbles which appear before a pan of water begins to boil are bubbles of air and not bubbles of steam.

Water is not the only solvent we have, although it is probably the most useful. Gasolene, alcohol, ether, benzene, turpentine and coal oil are all solvents. Some substances which are insoluble in water may be dissolved in other solvents. Oils and fats do not dissolve in water but they do dissolve readily in gasolene, ether, and coal oil. This is why clothes soiled with oil, are often cleaned with gasolene.[1] Alcohol is used as a solvent for many drugs which are to be used as medicines.

Why We Wash With Soap. Although oils do not dissolve in water they can be made to mix thoroughly with it to form what is called an *emulsion.* This is done by putting another substance in the mixture. Soap is often used to cause oil and water to form an emulsion. When oil, soap, and water are shaken together the oil breaks up into small droplets. The soap forms a film around each droplet. The soap film prevents the oil droplets from reuniting and so they do not float to the surface but remain mixed with the water.

Because soap causes oils to form an emulsion with water, it is used as a cleaning agent. Grease and oils on the skin and clothing are emulsified by soap and can be rinsed off with water. Particles of dirt are removed with soap in a similar way. The soap causes the dirt particles to become suspended in a soap solution. As the clothes are rinsed the soap and dirt are rinsed away. Cleanliness and health go hand in hand. Bacteria may accumulate on the clothes and skin during the day. Later they may cause disease. They are washed away with soap and water. Soiled clothes are made clean and attractive by laundering them with soap and water.

1 Because gasolene is so inflammable it is dangerous to use for cleaning clothes. There are other solvents for grease which are not inflammable. Carbon tetra chloride is one of these.

Soap helps water to clean the skin properly. In the skin are numerous pores or small openings. When these pores become clogged with dirt the sweat glands cannot get rid of waste matter. When this waste matter is held beneath the skin in this way pimples and blackheads are caused. This waste matter also causes sickness when it is prevented from escaping (Fig. 249).

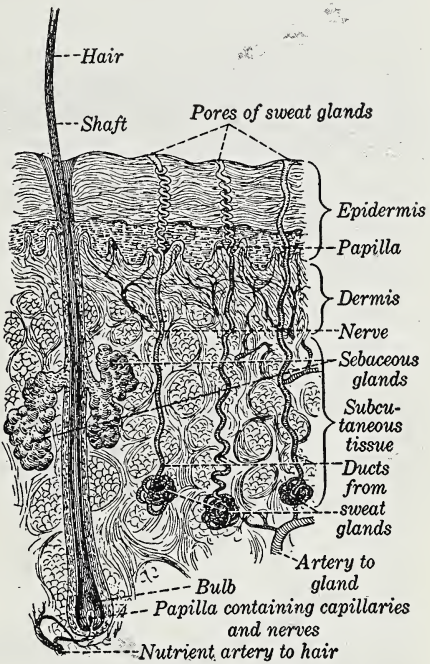


Fig. 249.—A Section of Skin, Highly Magnified

How Soap is Made. The making of soap is one of man's oldest chemical industries. Soap is made by the action of a strong alkali such as lye on animal and vegetable fats and oils. Many different fats and oils are used in soap manufacture. Whale oil, beef fat, olive oil, cocoanut oil, and cotton seed oil are used. In the soap factory the fat is placed in a large cauldron with a strong solution of alkali. It is heated for several days. When the alkali acts upon the fat, soap and glycerine are formed. Glycerine is therefore a by-product of soap manufacture (Fig. 250).

The early pioneers of Canada made their own soap. They obtained alkali from the wood ashes of their winter fires. The ashes were placed in a barrel in layers with lime and straw

Courtesy Proctor and Gamble Co. of Canada, Limited

Fig. 250.—A Modern Soap Factory

In the top picture are the vats for boiling soap. Below are shown blocks of soap ready for cutting into bars.

between the layers. In the spring, water was poured into the barrel to dissolve the "potash", as the alkali so formed was

called. The potash solution was used with fat to make a soft soap (Fig. 251).

Hard and Soft Water. Natural water often has chemicals dissolved in it. When rain water seeps through the ground it dissolves mineral salts. Sometimes the water passes through soil containing such salts as bicarbonate of calcium, sulphate of calcium and sulphate of magnesium. When water dissolves these

Courtesy Proctor and Gamble Co. of Canada, Limited

Fig. 251.—Making Soap on the Farm

In the picture on the left water is being poured through wood ashes to obtain the alkali. The other picture shows the alkali boiled with fat to produce soap.

salts it is called *hard water*. Soap does not easily form a lather with hard water. It cannot form an emulsion with grease and dirt unless it will form a lather. Water, such as rain water, which does not have mineral salt dissolved in it is called *soft water*. Soap easily forms a lather with soft water. Hard water must be softened before soap will form a lather with it. Much soap is used up in softening the water. The soap combines with

the dissolved mineral salt to form insoluble substances which merely float in the water. Water which is hard because it contains bicarbonate of lime can be softened by boiling it. The boiling causes the bicarbonate of lime to change to insoluble calcium carbonate or limestone. The limestone settles upon the side of the kettle and forms a hard rock-like deposit or scale. Water which can be softened by boiling is called temporary hard water. Water which is made hard by such salts as sulphate of calcium and sulphate of magnesium cannot be softened by boiling. Soap may be used to soften such water but it is expensive to do this. Cheaper softeners, such as borax and washing-soda may be used.

Guide Words

frozen	liquid	solid
gas	states of matter	expansion
red hot	white hot	filter
sweat glands	expand	contract
thermometer	boiling temperature	freezing temperature
centigrade	Fahrenheit	100 degrees centigrade
emulsion	soap	0 degrees centigrade
pressure-cooker	crude oil	petroleum
solution	solute	solvent
suspended	pores	hard water
soft water	temporary hard water	permanent hard water
heat	pressure	distillation
insoluble	saturated	

Signpost Sentences

1. There are three ....; solid, liquid and gas.
2. .... is often used to change matter from a solid state to a liquid state or from a liquid state to a gaseous state. Cooling has the opposite effect.
3. Heat causes matter to .... because the molecules in it move faster when heated; cooling causes matter to .... because the movement of the molecules decreases.
4. .... and .... of water are constant when the air-pressure is constant.
5. When the .... on water is increased the boiling temperature is higher.
6. The scale of degrees on a .... are determined by the boiling point and freezing point of water.
7. Because different liquids have different boiling points, a mixture of liquids, such as is found in crude oil, can be separated by ....

8. Two substances can form a .... without losing their chemical natures.

9. When sugar is dissolved in water the sugar is called the ...., the water is called the ...., the two make a ....

10. Many substances which are .... in water can be dissolved in other solvents.

11. A solution is .... when the solvent will dissolve no more of the solute.

12. Substances like oil which do not dissolve in water can be made to form an .... with the water.

13. .... causes grease and dirt to become emulsified in water.

14. Distilled water and rain water are .... They contain no ....

15. .... can be softened by boiling.

16. .... can be softened by using soap or chemical softeners.

Questions on the Chapter

1. Name several kinds of solid matter, several kinds of liquid matter and several kinds of gaseous matter.
2. Explain why water pipes are burst when they are frozen.
3. Why does ice float?
4. How would you show that solids, liquids and gases expand when heated?
5. How does heat cause matter to expand?
6. How do you test a thermometer to see if it is correctly marked?
7. Why does it take longer to cook food by boiling it at high altitudes than at sea level?
8. Why does food cook more quickly in a pressure-cooker than in an ordinary pot?
9. How is gasolene separated from crude oil?
10. How could you prove that the chemical nature of sugar is not changed when it is dissolved in water?
11. How could the sugar be recovered from a solution?
12. If you had a cold saturated solution of sugar what could you do to make more sugar dissolve?
13. How could you remove a grease spot from cloth if you did not wish to wash the cloth with soap and water?
14. How is soap made? What by-product is obtained from soap making?
15. Why does muddy water become clear on standing?
16. How does soap and water clean soiled clothing?
17. Why should the skin be kept clean?
18. How can temporary hard water be softened?
19. How does soap soften hard water?

Special Problems and Practical Applications

1. What use is made of the glycerine obtained in the manufacture of soap?
2. Why is mercury usually used as the expanding liquid in thermometers?

3. Explain what precautions against damage from expansion and contraction are taken (a) In laying cement sidewalks. (b) In laying railroad tracks. (c) In stringing electric wires.

4. Why does a milk bottle crack when boiling water is poured into it?

5. If there is an oil refinery in your locality arrange to visit it. Report to the class on the methods used in separating the oils.

6. If you are able to visit a soap factory, do so and report to the class on the methods used in manufacturing soap.

7. Why is water not used in thermometers?

8. Why is alcohol used in thermometers which register very cold temperatures?

9. How are the pistons in an auto engine prevented from ''jamming'' when they expand with heat?

10. When the metal top of a sealer sticks it can often be removed by first dipping the top in hot water. Explain.

11. Why does the garage man put distilled water in the battery of a car?

12. In some localities the tea-kettle becomes coated with a rock-like scale. Why?

13. How does anti-freeze protect the radiator of an automobile?

14. How does the thermometer on an oven door work?

Home Projects

1. Fill a bottle with water and allow it to freeze by placing the bottle outdoors during frosty weather. Account for what happens.

2. Examine concrete sidewalks to discover what provision is made for expansion and contraction caused by changes in temperature.

3. Make a thermometer. Use a bottle, a glass tube and a cork.

4. Into two separate bottles pour a mixture of water and charcoal. Make a soap solution by mixing soap and water. Into one bottle pour some of the soap solution. Shake both bottles well and allow them to stand for a few hours. Account for the result. When the bottles are emptied notice which one of the two is the cleaner. Can you explain why there should be a difference?

5. Test the ''hardness'' of the water in your home Make a soap solution with distilled water and soap. Put a measured quantity of distilled water in a bottle. Add soap solution one drop at a time. Shake well after each addition of soap solution. Note the number of drops that are necessary to cause the distilled water to form a lather with the soap solution. Repeat the process using water from the tap. Is there a difference in the number of drops of soap solution needed to form a lather with tap water? Is your tap water hard or soft?

CHAPTER XXIII

THE SCIENCE OF LIVING THINGS

Can you answer these questions?

1. Can sunshine be used to make food?
2. Can the sunlight of summer be stored for winter use?
3. What is energy?
4. Why do we need energy-producing foods?
5. Why is spinach a healthful food?
6. What causes foods to decay?
7. How can you prevent foods from spoiling?
8. What causes disease?
9. Why do we "catch" some kinds of disease from sick people?

Elements in the Body. The living cells which compose our bodies are made of many different chemical compounds. When these compounds are decomposed they are found to consist chiefly of carbon, hydrogen, and oxygen. Combined with these three may be found small quantities of nitrogen, sulphur, calcium, iron, phosphorus or sodium.

One might suppose that if he were to eat the proper quantities of each of these elements the digestive organs of his body would convert them into flesh and bone. Such, however, is not the case. Phosphorus by itself is a deadly poison; sodium and calcium are metals which would form harmful compounds the moment that they came in contact with the water of the stomach; carbon and sulphur are tasteless substances which by themselves have no food value.

In order to live and grow you must have the proper kind of food. This food supplies the elements required to build the compounds of your body. Food contains these elements in a

form which the digestive organs can use without harm to you. No one kind of food will supply the body with all the elements it needs. You require, therefore, a variety of foods.

Energy. You need foods not only because of the elements they contain but also because you require energy to live and move. When you move about from one place to another you are doing work. In order to cause movement (or to do work) energy is required. Foods supply the body with energy and give it the ability to move. Labourers, who do heavy work, require more food than office workers, who do light work. Extra food is required to supply the energy to do the work.

To understand why foods provide you with energy to do work you must learn more about energy and its uses. Energy is used in many ways to cause movement. Energy causes automobiles to move. When you see an automobile moving swiftly along the road you think of it as a powerful machine. It has, however, no energy of its own. Before it can move gasolene must be burned in the cylinders of the motor. When gasolene is burned energy is released. This released energy moves the automobile. Before a railroad engine can move energy must be released from burning fuels in the firebox (Fig. 252). Energy in the form of an electrical current passes through the motors of a street-car and causes the car to move. A man can move because chemical action releases energy in the muscles of his body.

Light, heat and electricity are three forms of energy. Chemicals and moving objects can be used to do work. This means that they also possess energy. The energy possessed by chemicals (e.g., gasolene, gunpowder) is called chemical energy. The energy possessed by moving objects (e.g., falling water) is called *kinetic* energy.[1]

One form of energy can be changed to another form. For example, when an electric current is passed through the wires of the globe of an electric light, the electrical energy of the current is changed to the energy of heat, and the energy of light. When

[1] "Kinetic" is derived from a Greek word meaning "moving".

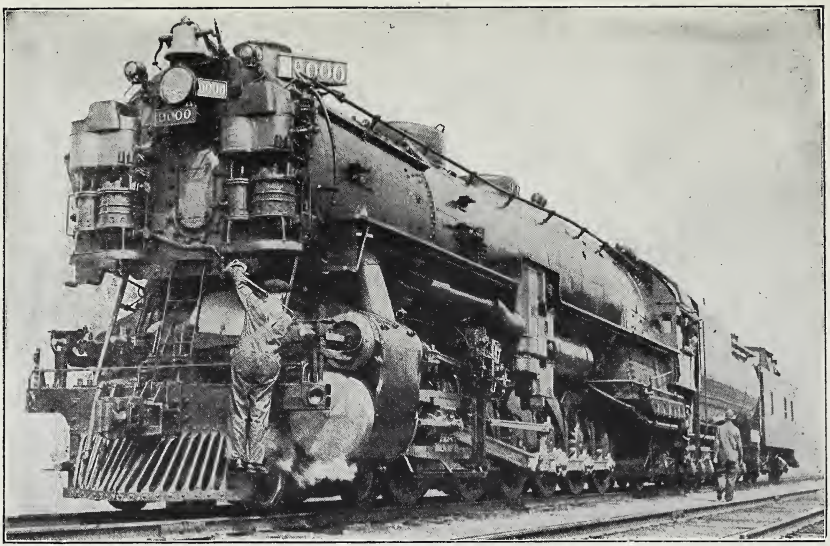


Fig. 252.
The locomotive moves because burning fuels release energy.

water which flows down hill is used to turn electric generators the kinetic energy of the moving water is changed to electrical energy. This same electric energy can be changed back to kinetic energy by using it to run electric motors. These motors could cause water to be pumped upwards again.

Although energy can be changed from one form to another it cannot be created from nothing. It must already exist in one form or another. When we burn wood or coal, we obtain the heat energy of the fire. We did not create that energy. It was already in the fuel in the form of chemical energy. When the carbon in the fuel combines with the oxygen of the air this chemical energy becomes heat energy and is released. When all of the carbon in a piece of wood has combined with oxygen no more heat can be obtained from the carbon and oxygen. These two elements have combined to form the compound carbon dioxide. If the carbon and the oxygen of this carbon dioxide could be separated they would combine again and so produce more energy in the process. But in order to decompose the carbon dioxide into carbon and oxygen as much energy would have to be used as was obtained from the burning wood.

The Body Needs Energy. Certain foods are valuable because they contain energy in a form which can be used by the body. What are these foods? Whence do they obtain their energy? Practically all of our food comes either from plants or from animals. Since the animals which supply us with meat, eggs and dairy products depend, in turn, upon plants for their food we may consider all of our food to be of plant origin.

The Food Factory. Plant cells, like animal cells, are composed of chemical compounds. Animal cells require food to build up these compounds. Plant cells, however, can manufacture their food from the minerals of the soil, from water and from carbon dioxide. Carbon dioxide, minerals and water, by themselves, do not possess energy in a form which we can use Yet the food which is manufactured by the plant does contain energy. Where does the plant obtain this energy? How do

plants convert carbon dioxide, water and minerals into foods? The mineral salts and water which the plant requires are obtained from the soil. Water containing dissolved mineral salts passes from the soil into the root-hairs which are on the roots of the plants. From the root-hairs the water and dissolved mineral salts enter the wood-fibres (water-ducts) of the stem of the plant. These wood-fibres are tube-like cells which conduct the water and the materials dissolved in it to the leaves of the plant. In the leaves these materials come into contact with the carbon dioxide of the air. The water and carbon dioxide are converted into the compound sugar.

The leaf is the laboratory where this chemical change takes place. By means of a microscope it is possible to examine the structure of the leaf and so to learn much concerning these changes. On examining the leaf through a microscope it is found that the upper side of each leaf is covered with transparent cells (Fig. 253). These cells form an *epidermis* or skin through which sunlight can pass. Beneath this epidermis there is usually to be found a layer of long, or *elongated* cells, the *palisade* cells. Each of these palisade cells contains numbers of small bodies, the *chloroplasts*. The chloroplasts contain a green coloured material, *chlorophyll*. Beneath the palisade cells are usually to be found numerous loosely arranged cells which also contain chloroplasts. Between these latter cells are air-spaces.

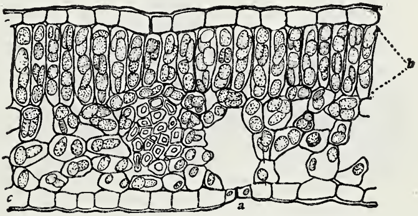


Fig. 253.—Section of a Leaf Showing the Air Spaces

Breathing-pore or stoma at *a*. The palisade cells which chiefly contain the chlorophyll are at *b*. Epidermal cells at *c*.

The lower epidermis of the leaf is much like the upper epidermis except that in the lower epidermis are to be found num-

erous pores, called *stomata*. Carbon dioxide from the air enters the leaf through these stomata. The carbon dioxide and water in the leaf are converted into sugar by means of chlorophyll. Sugar, however, contains energy. In order to convert carbon dioxide and water into sugar the plant must have a source of energy to perform this task. This energy is obtained from sunlight.

Because sugar is a compound of carbon and water it is called a carbohydrate. Plants change the form of the carbohydrates which they manufacture by rearranging the atoms in the molecules. Starch is one of the carbohydrates formed in plants by such a change. Almost as soon as sugar is formed in the leaf it is changed to starch. In the following way you can demonstrate that the energy of sunlight is required before starch can be produced in a leaf.

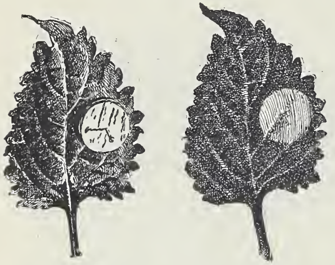


Fig. 254.
The cork prevents the sunlight from reaching the chlorophyll in the cells beneath it.

Testing for Starch in the Leaf. Procure a potted plant with large leaves. Place the plant in a dark cupboard and allow it to remain there for twenty-four hours.[1] Now place the plant on a window-sill where it will receive plenty of direct sunlight. On the upper side of one of the leaves pin a thin slice of cork. Allow the plant to remain in sunlight for several hours. Then remove the leaf and boil it in water for two minutes. Remove it from the water and place it in methylated spirit for a few minutes. Chlorophyll will dissolve in methylated

[1] If the plant has been in the sunlight its leaves will already contain starch. If the plant is placed in darkness this starch will be converted to sugar once more. This sugar will then pass from the leaf through the sap-ducts to all parts of the plant where it is used up as food. If the plant is then left in darkness for a day, there will be no starch in the leaves at the beginning of the experiment.

spirit (alcohol) and is in this way removed from the leaf. Observe that the chlorophyll colours the alcohol green. When the leaf becomes white it is a sign that the chlorophyll is all removed. Now place the leaf in a solution of tincture of iodine (iodine dissolved in alcohol). Iodine causes starch to be coloured blue. You will notice that the leaf turns blue except in the spot which was covered by the cork (Fig. 254). The cork has prevented the sunlight from reaching the chorophyll in the cells beneath it. Without sunlight the chorophyll was unable to convert carbon dioxide and water into sugar. Consequently since there was no sugar in that part of the leaf the carbohydrate, starch, could not be formed.

Fig. 255.—Carbohydrate Foods

Carbohydrates as a Store-house of Energy. When sugar and starch are produced sunlight energy becomes stored in them. During this process of making sugar and starch the carbon dioxide which the plant obtains from the air is decomposed into carbon and oxygen. The carbon combines with water to form the carbohydrate sugar. The oxygen is returned to the air through the stomata on the lower epidermis of the leaf.

The process by which a plant builds up carbohydrates from carbon dioxide and water with the aid of sunlight and chlorophyll, is called *photosynthesis*.[1]

When we burn carbon we convert the chemical energy of carbon and oxygen into heat energy. In this process carbon dioxide is produced. When carbohydrate compounds are burnt up they release this heat energy. By means of the process of photosynthesis plants are able to convert the abundant sunlight

[1] Photosynthesis: building up by means of light.

energy into chemical energy which is stored up in carbohydrate compounds. Plants and animals alike obtain their energy from these carbohydrate foods. All the energy which enables living beings to move is just another form of sunlight energy. Plants convert the sugar and starch, which they make, into many other compounds such as wood, oil, pitch and different sugars. Of these man uses the starches, the sugars and some of the oils as food.

We use these carbohydrates such as starches and sugars and also the fats and oils because they are energy-producing foods. We need energy-producing foods to enable us to live and move. Because they are constantly using up energy the muscle-cells in our bodies require these foods most.

Fig. 256.—Fat Foods

Starches are good energy-producing foods. Plants supply a wide variety of starches. Among the starches are to be found corn starch, wheat starch, potato starch and arrow-root starch. Grain, potatoes and most vegetables contain starch. Most of the sugar of our food comes from sugar-cane or from sugar-beets, although we obtain some from other sources such as sweet fruits, the maple tree and honey from the nectar of flowers. Fats and oils are also valuable heat and energy-producing foods. Fats and oils are much alike. They differ in that fats are solid at ordinary temperatures while oils are liquids. Digestible oils such as cottonseed oil and olive oil are obtained directly from plants. Other fats and oils such as lard and butter are obtained from animals. (Mineral oils produced from petroleum are useless as foods.) Much fat and oil are obtained from eggs, cheese, chocolate and corn.

Foods for Man. Heat and energy-producing foods are not

the only foods obtained from plants. As they grow, plants require and produce many kinds of compounds. Like animals, plants are composed of cells. Each living cell contains a living jelly-like substance called *protoplasm*. Protoplasm can be separated into a number of different compounds. Protein is one of these compounds. Protein contains carbon, hydrogen, oxygen and also nitrogen and sulphur. The nitrogen, sulphur and other minerals which the plant requires in order to make protoplasm are obtained from the soil. From these mineral salts and from carbohydrates plants are able to produce proteins. These proteins are used in turn to produce living protoplasm.

Protoplasm is found also in the cells of the body. It is the living part of the cell. The cells of the human body are not able to construct protoplasm from carbohydrates and mineral salts

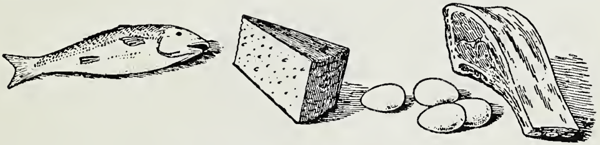


Fig. 257.—Protein Foods

as the plant cells do. In order to make protoplasm in their body cells both human beings and other animals require protein. The protein builds the protoplasm of new cells. It also repairs the protoplasm which is used up as the cells live. There are still other materials needed by the body besides protein and energy-producing foods. Foods containing minerals are necessary: calcium is needed to build bone; a small amount of iron is necessary for the building of red blood cells; salt is needed in the blood. Milk, eggs, fruit, and vegetables are rich in minerals.

Vitamines. It has recently been discovered that certain foods contain other substances necessary for health and growth. These substances are called *vitamines*. Chemists do not know as yet the exact chemical composition of all vitamines but they do know that illness results when the body does not receive a sufficient supply of

vitamine from the food. There are several kinds of vitamines. Vitamine "A" is found in butter, lettuce, cabbage, fish and liver. When this vitamine is absent from the diet, growth does not take place and the eyes become sore and inflamed.

Vitamine "B" is found in eggs, liver, whole grains, beans, peas and milk. In Japan and China where the diet is chiefly polished rice a disease called beri-beri is common. Polished rice does not contain vitamine "B". When unpolished rice or even rice polishings are eaten the disease of beri-beri is cured. Rice polishings contain vitamine "B".

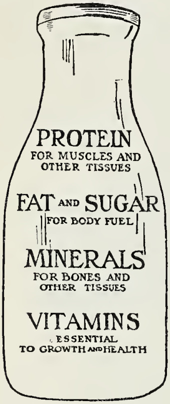


Fig. 258.—The Most Nearly Perfect Food

Vitamine "C" is found in cabbage, turnips, tomatoes, oranges and in fresh fruit generally. When in former times sailing ships were often several months away from land fresh vegetables and fruits which supply vitamine "C" could not be obtained. Because of the lack of vitamine "C" sailors often became sick with a disease called scurvy.[1]

A Balanced Diet. It is clear from what you have learned about foods that a great deal of care must be given to the selection of food; you should have a *balanced diet.* Your diet should contain:

1. Proteins to build and replace tissue or flesh;
2. Carbohydrates to supply heat and energy;
3. Minerals to build teeth, bone, and blood;
4. Vitamines to assist the body to keep healthy.

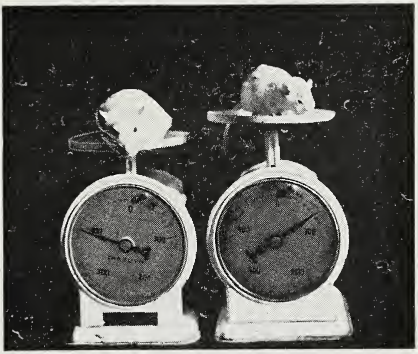
It is also evident that you should have a proper amount of each kind of food. No hard and fast rule can be given for selecting your foods. The kind of work you are doing, the seasons of the year, and your own tastes influence the selection of your foods. The following suggestions, however, will help you select a properly balanced diet:

A. Although a moderate amount of protein food should be

[1] See Appendix II with reference to vitamine D.

eaten excessive amounts should be avoided. Whole-wheat bread, meat, milk, eggs, fish, cheese, peas and beans furnish proteins.

B. The diet should include suitable amounts of carbohydrates, fats and oils. In the winter the amounts of these heat- and energy-producing foods should be increased. Bread, corn, potatoes, oatmeal porridge and butter are excellent heat and energy-producers.



Courtesy Ayerst, McKenna and Harrison, Limited

Fig. 259.—The Effect of Vitamines in the Diet

The rat on the right was fed on a diet containing no vitamines. The one on the left was fed on a diet containing vitamines.

C. The body requires such elements as calcium, sodium, phosphorus, iron and sulphur. Foods which contain these are called mineral foods. Your diet must contain mineral foods. Green vegetables such as lettuce, brussels sprouts, and spinach are rich in minerals. Milk, clams, fish and cheese also contain many necessary minerals. Although most minerals are obtained by digesting foods, salt is an exception. It is merely mixed with the food and eaten directly. Water also is a mineral food.

D. Your diet should include foods which contain vitamines. You can obtain vitamine "A" from butter, cream, eggs, whole milk and spinach; Vitamine "B" from beans, raw cabbage, spinach and tomatoes; Vitamine "C" from lettuce, tomatoes, raw cabbage, oranges. There are still other vitamines to be obtained from cod-liver oil, liver and egg-yolk.

To sum up these rules a good diet might contain a little meat,

bread, butter, plenty of milk, vegetables, especially green vegetables and fresh fruit. Children should eat enough food to keep up the strength and to permit the proper development of the body.

Your diet should include also some bulky food. Vegetables such as carrots, cabbage, turnips, and celery contain wood-fibre. Although this wood-fibre is not digested and has no food value, it stimulates the muscles of the intestines and keeps them healthy.

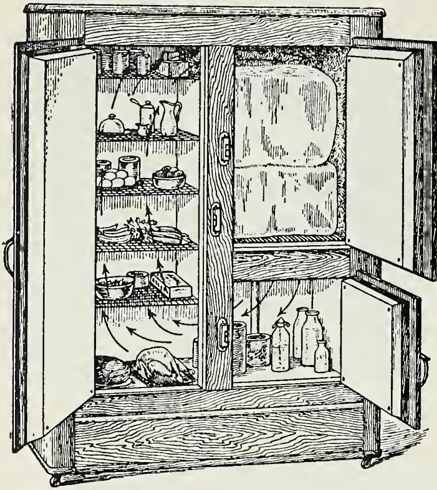


Fig. 260.—Preserving Food in a Refrigerator

Bacteria and Decay. Care should be taken to keep perishable foods, such as meat, milk, eggs and fresh vegetables, from spoiling. Spoiled foods are unwholesome. As foods decay the proteins in them are likely to decompose and form poisons. Decaying meat often causes *ptomaine* poisoning. To prevent meat and other food from decaying they are kept in refrigerators (Fig. 260). The cold of the refrigerator stops the growth of bacteria.

The decay of foods is caused by bacteria which grow in them. The bacteria produce *ferments* which cause the decay. Bacteria are the simplest kinds of living things. Each bacterium is a single cell so small that a powerful microscope is needed to see it. A bacterium is a *fungous* plant. It does not contain chlorophyll and so is unable to manufacture its own food. It secures its

food from the material in which it grows. When a bacterium is fully grown it divides into two new bacteria. These in turn when fully grown divide in two again, thus producing four bacteria. When conditions for growth are suitable the bacteria may divide in this way every twenty minutes. In a few hours one bacterium may multiply into many millions of bacteria.

Foods will not decay unless bacteria are present in them. Foods may be preserved by *sterilizing* them. Sterilizing means killing all the bacteria which the food contains. To sterilize them, foods are often "canned". The food is sealed in a can and is then cooked in a pressure-cooker at a temperature which kills all the bacteria. The food in the can will "keep" until the can is opened. When the can is opened, bacteria of decay which are always present in the air settle on the food and grow in it. This is why canned goods begin to spoil after being opened.

Fig. 261.—Yeast Plants (Highly Magnified)

Yeast plants are fungous plants. They produce a ferment which changes sugar to alcohol.

Besides warmth and suitable food bacteria requires moisture in order to grow. Many foods, such as rice, peas and beans can be kept by merely keeping them dry.

Other foods are preserved by supplying a substance which prevents the growth of bacteria. Meats are preserved by being pickled in vinegar. Fish are preserved with salt. Some fruits are preserved with sugar. Ham and bacon are preserved by chemicals contained in the smoke from certain barks.

There are many kinds of bacteria and fungous plants and many kinds of ferments. Not all of them are harmful. For example, yeast is a fungous plant which produces a ferment that changes sugar into carbon dioxide and alcohol. Advantage is taken of this when yeast is used to make bread "rise". The bubbles of

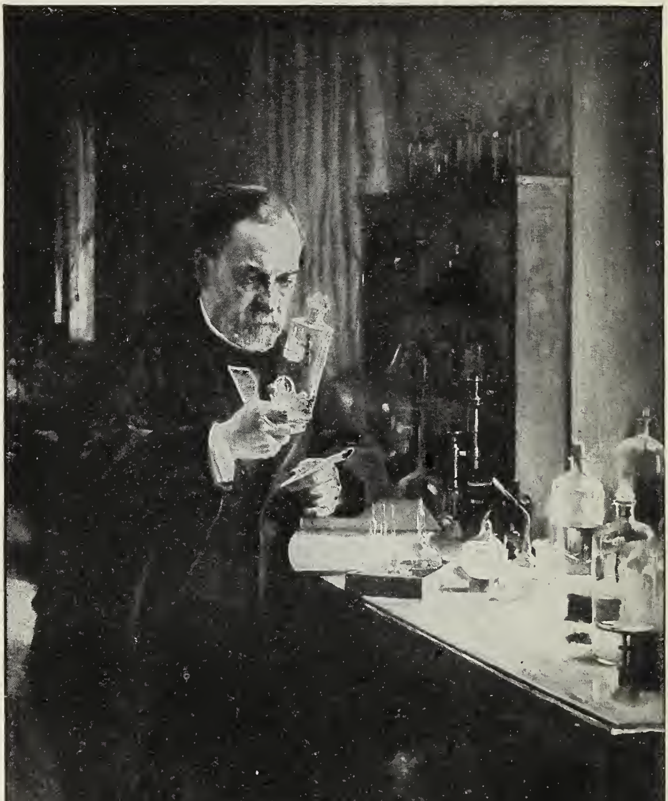


Fig. 262.—Louis Pasteur

carbon dioxide which form in the dough give lightness to the bread. In the making of cheese from milk the ferment produced by cheese bacteria cause the curds of cheese to form.

Bacteria and Disease. Louis Pasteur, a French scientist (Fig. 262), discovered that certain kinds of bacteria cause disease when they grow in the body. These disease-producing bacteria are commonly called disease germs. (Fig. 263). As they grow in the body they produce *toxins* or poisons. These toxins may destroy the body tissues in the neighbourhood of the growing bacteria or they may be carried by the blood to the other parts of the body and cause harm there.

Fig. 263.—Types of Disease Bacteria (Highly Magnified)
(a) Tuberculosis; (b) Diphtheria; (c) Typhoid Fever; (d) Vibrio of Cholera; (e) Anthrax; (f) Erysipelas; (g) Pneumonia

There are many thousands of kinds of bacteria. Only a few kinds, however, cause disease in human beings. Before they can cause disease they must in some way enter the body. But the body is well protected against their attacks. Germs cannot pass through the skin unless it is broken or cut. When the skin is scratched or broken, germs which might enter the body may be killed by applying a solution of iodine to the wound.

Pasteurizing Milk. Bacteria sometimes enter the body through the mouth. For this reason it is important that care be taken to keep foods free from harmful bacteria. Although milk is one of our most valuable foods it is also an excellent food for bacteria. We should therefore be careful to prevent harmful bacteria from getting into milk and growing there. In good,

modern dairies care is taken to see that milk is kept clean and that it is not handled by people who have bacterial diseases. To prevent the growth of bacteria which might be in the milk it is kept cool. To prevent the introduction of bacteria into the milk from milk tins and bottles, these are sterilized before milk is put in them. This is done by placing them in scalding water.

How the Body Protects Itself Against Disease Germs. Even with all these precautions disease-producing bacteria may be found in milk. For this reason milk is often *pasteurized* to destroy harmful bacteria which might be in it. This pasteurizing is done by heating the milk for twenty minutes to a temperature between 150°F and 155°F. When milk is pasteurized not all of the bacteria in it are killed. Certain harmless bacteria, which do not cause disease are left in the milk. These bacteria will in time cause the milk to become sour. Disease bacteria do not grow in sour milk.

Fig. 264.—White Corpuscles and Bacteria

A, a white corpuscle devouring a bacterium. B, a white corpuscle destroyed by bacteria.

Sometimes harmful bacteria do reach the stomach when foods containing them are eaten. In most cases these bacteria are destroyed by the acids of the stomach. Occasionally, however, bacteria enter the body through the thin skin which lines the mouth, throat or intestines. When they enter the body in this way they may be attacked and destroyed by the white *blood-corpuscles*. These white blood cells or corpuscles are always present in the blood. Bacteria are taken in and digested by these cells. But when the white blood-corpuscles are unable to destroy all the bacteria the disease makes headway. When this happens the body produces *antitoxins*. *These anti-toxins are chemicals which neutralize or make harmless the poisonous toxins produced by the bacteria.*

There are, however, people who are unable to resist attacks of disease in this way. Long and serious illnesses may then result from the development in the body of these disease-producing bacteria. The best way to protect yourself from disease is by avoiding contact with disease germs and by preventing their spread. You can help keep your body healthy and help in protecting yourself from disease germs by following the rules of health of the Junior Red Cross.

Rules of the Health Game

1. Wash the hands before touching food, and after using the toilet.
2. Keep the finger nails clean.
3. Brush the teeth every night and every morning.
4. Use a handkerchief over your mouth when coughing or sneezing.
5. Take a warm bath at least once a week.
6. Do not spit.
7. Keep fingers, pencils, pens, erasers and rulers away from mouth and nose.
8. Hold the body straight while sitting and standing.
9. Drink plenty of water every day, but no tea or coffee.
10. Eat plenty of vegetables and fresh fruit every day, but not much meat.
11. Play out of doors every day.
12. Sleep with the windows open.

Guide Words

sunlight
oils
decay
antitoxin
carbo-hydrates
vitamines
sterile
starch
iron
toxins
chemical compounds
mineral foods
carbon dioxide
calcium
fungus
chloroplasts
protein
ptomaine poison
blood-corpuscles
fats
balanced diet
yeast
foods
disease germs
energy
salt
refrigerator
sugar
phosphorus (*noun*)
phosphorous (*adjective*)
chlorophyll
protoplasm
bacteria
green plants

Signpost Sentences

1. The materials of which the human body is composed are ....
2. The elements which compose the body compounds are obtained from ....
3. Foods come directly or indirectly from ....
4. .... are energy-producing foods.
5. With the aid of sunlight and .... green plants manufacture sugar from carbon dioxide and water.
6. .... is stored in the carbohydrates manufactured by plants.
7. To build and repair the living .... the body requires foods which contain proteins.
8. The body requires .... foods as well as carbohydrates and proteins.
9. A lack of .... in the food may prevent proper growth and may also cause sickness.
10. Food .... is caused by bacteria.
11. .... are single-celled plants.
12. Some kinds of bacteria cause diseases. These kinds are commonly called ....
13. Disease germs cause sickness by producing .... or poisons.

Questions on the Chapter

1. How does the human body obtain the elements which are required to build it?
2. Explain the statement—"Most foods are obtained directly or indirectly from green plants."
3. What things are necessary in order that plants may manufacture sugar?
4. How could you prove that plants require sunlight in order to make starch?
5. Name three different forms of energy.
6. Of what value are carbohydrates and oils as food?
7. Of what value are proteins as foods?
8. Name some foods which contain minerals.
9. Name several foods which contain vitamines. Why are vitamines necessary in food?
10. Why do foods decay?
11. How do bacteria increase in number? At what temperature do they thrive best?
12. How can the growth of bacteria be checked?
13. How can bacteria be destroyed?
14. Why is milk often pasteurized?
15. How do disease bacteria cause sickness?
16. How does each of the following protect the body from the attacks of disease germs? Skin, white blood-corpuscles, acid in the stomach, antitoxins.
17. Learn the rules of the health game.

Special Problems and Practical Applications

1. When the conditions are suitable cholera bacteria divide every twenty minutes. How many bacteria would be produced from a single cholera germ in ten hours, if all the bacteria lived?
2. Read the life story of Louis Pasteur and tell it to the class.
3. Visit one of the dairies in your locality to see what measures are taken to keep the milk free from harmful bacteria and to prevent bacteria from growing in the milk.
4. Koch and Lister were two scientists who discovered much about disease-producing bacteria. Read about them in the encyclopaedia.
5. What elements are found in the human body?
6. What foods would you include in a lunch in order to obtain a properly balanced diet? Give reasons for your selection.
7. What precautions should be observed in handling and in storing the following foods. Milk, meat, dried beans, vegetables, butter?
8. Visit a canning factory and observe how the foods are cleaned, canned and cooked.
9. Cupboards in which food is kept should be cleaned frequently. Why?
10. Flies assist in the spreading of many diseases. Can you explain why? How would you prevent flies from bringing diseases into your home?

Home Projects

1. You can demonstrate that yeast produces carbon dioxide when it ferments sugar. To do so place some yeast in a weak solution of molasses and water. Place this solution in an erlenmeyer flask or a small bottle. Put a one-holed stopper, fitted with a bent glass tube in the bottle. Put the open end of the glass tube into a tumbler containing lime-water. Allow the apparatus to stand in a warm place. How will the lime-water show if carbon dioxide is produced?
2. Test the following foods with tincture of iodine to see if they contain starch: (a) boiled potato; (b) flour; (c) white of egg; (d) milk; (e) oatmeal porridge.
3. You can make a home-made cooler to help keep perishable foods from spoiling. Make a wooden frame and cover it with fly screen. Make a cloth cover to fit loosely over the cooler. On top of the cooler place a dish of water into which the end of the cloth cover dips. Capillarity keeps the cloth moist. Evaporation from the cloth keeps the interior cool.
4. Keep a record of your diet for a week. Do you think it is a well-balanced diet? Could you suggest how to improve it?
5. In the library you will find an account of the growing and manufacturing of sugar. Make a report on it to the class.
6. Secure some unpasteurized milk. Divide it into three equal portions. 1. Boil one portion and set it aside. 2. Pasteurize the second portion by heating it to between 150°F and 155°F and letting it stand until it cools. 3. Let the third portion stand as it is. Observe the three portions carefully from time to time. Test them each with a separate piece of litmus paper. What changes occur in each portion of milk? Which portion gives off an offensive odour after standing several days? Which sample became sour first? Does pasteurization help to keep the milk from spoiling?

APPENDIX I

(See Preface, page x)

Test on Chapter I

Are you a careful reader? You can make a test of your reading ability by filling in the blanks of the following sentences.

1. Classified knowledge is called 1..................
2. The science of living things is 2..................
3. The scientific method of learning finds things out by 3..................
4. An "empty" jar is really full of 4..................
5. The science of the stars and heavens is called 5..................
6. A tank which contains air and which is used to enable men to work under water is a 6..................
7. In order to do an experiment we usually require 7..................
8. The way in which materials are used to solve a problem is called the 8..................
9. The statement of what is observed by the use of materials is called the 9..................
10. The last step in a scientific experiment is the 10..................
11. The science of the stars is called 11..................
12. Six scientists mentioned in Chapter I were:

(a)................. (d).................

(b)................. (e).................

(c)................. (f).................

Test on Chapter II

Some of the following statements are true and some are false. If a statement is true draw a circle around the "T", if it is false draw a circle around the "F". In scoring your answers subtract the number you get wrong from the number you get right.

1. T : F It is possible for water to become invisible.
2. T : F Because the sun evaporates water from the oceans, the oceans may dry up.
3. T : F Ice and steam are both forms of water.
4. T : F Rain-water is fresh water.

5. T : F It is impossible for life to exist without a supply of water.
6. T : F Most of the early settlements were built inland.
7. T : F The air in summer contains very little water vapour.
8. T : F When air is cooled the water vapour in it condenses.
9. T : F Dew is formed when water vapour condenses on cold objects.
10. T : F The air contains millions of particles of dust.
11. T : F Fogs are quite different from clouds.
12. T : F A cloud is fog in the upper air.
13. T : F Under the influence of the sun's heat, water passes off into the air by evaporation.
14. T : F When water evaporates it appears to dissolve into the air.
15. T : F Water vapour is an invisible gas.
16. T : F When water evaporates from the ocean salt evaporates with the water.
17. T : F Heat is required in order for water to change to water vapour.
18. T : F Water may evaporate even in cold weather.

Test on Chapter III

Multiple Choice

Write down in the space at the right the word or phrase which correctly completes each statement.

1. Man depends upon: (*a*) oceans, (*b*) evaporation, (*c*) water cycle, (*d*) condensation, for his supply of fresh water. 1. ....
2. Water which runs off the surface of the soil is called: (*a*) watershed, (*b*) run-off water, (*c*) water table, (*d*) soil water. 2. ....
3. Water may enter the soil: (*a*) because the particles are packed closely, (*b*) because particles are very fine, (*c*) because there is air in the soil, (*d*) because there are spaces between the particles. 3. ....
4. The layer in the soil through which water does not pass easily is called: (*a*) water-table layer, (*b*) impervious layer, (*c*) strata layer, (*d*) rock layer. 4. ....
5. The level of water in a well is the level of: (*a*) run-off water, (*b*) the water in the ocean, (*c*) the water table. 5. ....
6. When water dissolves lime or other mineral salts from the soil it is said: (*a*) to be hard water, (*b*) to be soft water, (*c*) to contain germs. 6. ....
7. Bacteria in water can be: (*a*) easily seen, (*b*) seen with the naked eye, (*c*) seen with powerful microscope, (*d*) seen with a hand magnifying lens. 7. ....
8. By filtering water: (*a*) mineral salts, (*b*) lime, (*c*) suspended particles, (*d*) all germs, can be removed from it. 8. ....

9. To prevent germs from getting into it the top casing of a well should be lined with: (*a*) boards, (*b*) bricks, (*c*) stones, (*d*) concrete. 9. ....

10. Water from an artesian well: (*a*) gushes out, (*b*) has to be pumped, (*c*) is difficult to pump, (*d*) exerts little pressure. 10...................

Test on Chapter IV

Fill in the blanks.

1. Individual wells are not suitable in large cities because they may become contaminated with 1. ....

2. The area from which a city gets its water supply must be uninhabited in order to prevent 2. ....

3. When a reservoir is situated so that the entrance to water-mains is higher than the highest point of the city the water is supplied to homes by force of 3. ....

4. The force with which water comes from a tap depends upon 4. ....

5. As height of water in the reservoir increases the pressure on the walls and at the bottom of the reservoir 5. ....

6. Impure water, containing only mud and other solid particles, may be made suitable for drinking by 6. ....

7. When the germs in water have all been killed the water is said to be 7. ....

8. A chemical which is frequently used to kill germs in water is 8. ....

9. Water may be flat and tasteless because it contains no dissolved 9. ....

10. In septic tanks sewage is destroyed by 10...................

MASTERY TEST ON UNIT 1.

Water

Match the first column with the second so that the letters in the first column correspond correctly with the numbers in the second.

A. filtering	evaporation and condensation	1...........
B. chlorinating	great danger in impure water	2...........
C. sand and gravel	does not evaporate when water boils	3...........
D. water cycle	water containing dissolved mineral salts	4...........
E. water vapour	takes place at all temperatures	5...........
F. water-pressure	through which water does not pass	6...........
G. typhoid germs	makes a good lather with soap	7...........
H. evaporation	excellent material for water filter	8...........
I. salt in water	water vapour condensed on cold objects	9...........
J. hard water	invisible gas	10...........
K. water table	water vapour condensed on dust particles	11...........
L. impervious layer	removes suspended particles from water	12...........
M. steam changed to water	science of living things	13...........
N. soft water	clouds close to earth	14...........
O. dissolving water in air	science of stars	15...........
P. biology	a method of sterilizing water	16...........
Q. fog	evaporation	17...........
R. clouds	level of water in well	18...........
S. dew	condensation	19...........
T. astronomy	depends upon height of column of water	20...........

APPENDIX II

In addition to vitamines A, B and C several others have been identified. Vitamin D, "the sunshine vitamine", is one of these. A lack of vitamine D causes rickets, a disease in which the bones become soft and pulppy. Without vitamine D the body cannot deposit calcium in the bones even though there is plenty of calcium in the diet. Rickets, as one would expect, is a disease more common in childhood when the bones are growing.

Unfortunately, with the exception of egg-yolk, most foods contain very little vitamine D. It can be obtained, however, from the oil found in the livers of some fish. Cod liver oil and halibut liver oil are particularly rich in vitamine D which accounts to a great extent for their value in medicine.

Although vitamine D is not found in many foods sunlight may cause it to be formed in the body. Ultra-violet light, the very short waves of sunlight, penetrate the skin and act upon certain substances in the body to produce vitamine D. This explains the occurrence of rickets in congested city districts where children do not obtain enough sunshine. In winter ultra-violet lamps may be used to supply artificial sunshine. Recently cereals and other foods have been treated with ultra-violet light. It has been found that under the influence of this light vitamine D is produced in them.

There are several other vitamines known at the present time. Their properties are being carefully studied.

INDEX

Page numbers in italics indicate illustrations

D

E

F

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DATE DUE SLIP

F. 255

Q 161 L733 1935
Limpus, George H.
General science for the
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